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Alt	n	GoFT									
		4	8	14	17	19	2	<b>29</b>	3	13	21
$P_1$	10	0.303	<b>0.838</b>	0.412	0.513	0.797	0.732	0.792	0.801	0.819	0.769
$P_2$		0.178	<b>0.267</b>	0.194	0.185	0.270	0.209	0.262	0.250	0.255	0.228
$P_3$		0.111	0.079	<b>0.112</b>	0.096	0.096	0.075	0.091	0.081	0.079	0.078
$P_4$		0.082	0.055	<b>0.083</b>	0.072	0.068	0.056	0.066	0.058	0.055	0.057
$P_1$	20	0.267	<b>0.994</b>	0.486	0.801	0.987	0.972	0.987	0.993	0.992	0.986
$P_2$		0.192	<b>0.589</b>	0.246	0.316	0.557	0.445	0.547	0.584	0.565	0.507
$P_3$		0.137	0.130	<b>0.148</b>	0.144	0.154	0.116	0.149	0.143	0.127	0.126
$P_4$		0.102	0.066	<b>0.106</b>	0.098	0.083	0.068	0.080	0.075	0.066	0.070
$NM_1$	10	0.107	0.081	<b>0.111</b>	0.097	0.099	0.080	0.097	0.081	0.081	0.081
$NM_2$		0.096	0.065	<b>0.098</b>	0.085	0.079	0.064	0.077	0.066	0.064	0.066
$NM_3$		0.059	0.050	<b>0.059</b>	0.056	0.054	0.051	0.054	0.050	0.050	0.051
$NM_4$		0.055	0.051	<b>0.056</b>	0.053	0.052	0.051	0.052	0.050	0.050	0.050
$NM_1$	20	0.119	0.125	0.132	<b>0.139</b>	0.156	0.124	0.148	0.131	0.125	0.128
$NM_2$		0.102	0.084	0.112	<b>0.113</b>	0.110	0.089	0.106	0.092	0.085	0.091
$NM_3$		0.063	0.051	<b>0.065</b>	0.062	0.056	0.052	0.056	0.053	0.051	0.052
$NM_4$		0.057	0.049	<b>0.057</b>	0.056	0.053	0.050	0.052	0.051	0.049	0.051
$NDPC_1$	10	0.139	0.111	<b>0.148</b>	0.136	0.142	0.117	0.137	0.114	0.113	0.117
$NDPC_2$		0.102	0.067	<b>0.102</b>	0.087	0.084	0.064	0.081	0.068	0.066	0.067
$NDPC_3$		<b>0.057</b>	0.050	0.057	0.053	0.053	0.049	0.052	0.050	0.050	0.050
$NDPC_4$		0.051	0.051	0.051	<b>0.052</b>	0.052	0.051	0.051	0.050	0.051	0.051
$NDPC_1$	20	0.137	0.193	0.170	0.214	<b>0.253</b>	0.216	0.246	0.207	0.200	0.218
$NDPC_2$		0.122	0.098	<b>0.133</b>	0.129	0.120	0.088	0.115	0.111	0.096	0.098
$NDPC_3$		<b>0.067</b>	0.051	0.067	0.062	0.055	0.052	0.054	0.054	0.051	0.053
$NDPC_4$		<b>0.051</b>	0.050	0.051	0.051	0.052	0.050	0.052	0.050	0.050	0.050
$PCM_1$	10	0.082	0.056	<b>0.082</b>	0.071	0.068	0.056	0.066	0.057	0.056	0.057
$PCM_2$		<b>0.065</b>	0.052	0.065	0.060	0.057	0.052	0.056	0.053	0.052	0.053
$PCM_3$		0.065	0.059	<b>0.066</b>	0.061	0.063	0.058	0.062	0.056	0.058	0.057
$PCM_4$		0.067	0.054	<b>0.068</b>	0.062	0.061	0.054	0.060	0.054	0.054	0.054
$PCM_1$	20	0.092	0.065	<b>0.097</b>	0.091	0.083	0.067	0.080	0.070	0.066	0.069
$PCM_2$		0.071	0.053	<b>0.072</b>	0.068	0.060	0.054	0.059	0.056	0.053	0.055
$PCM_3$		0.064	0.066	0.067	0.067	<b>0.074</b>	<b>0.068</b>	0.073	0.063	0.067	0.066
$PCM_4$		0.062	0.057	0.066	<b>0.066</b>	0.066	0.060	0.064	0.055	0.058	0.059

Source: authors' work.

Tables 6–13 present the power of the top ten tests for groups A-H of the alternatives. The highest values in each row are in bold. The GoFTs that stand out for the groups of alternatives based on the sum of powers are as follows:  $AD_{1,0}, AD_{0,9,0,1}, ADM^U$  (group A),  $AD_{0,1}, AD_{0,1,0,9}, ADM^L$  (group B),  $CVM, AD_{1,1}, AD_{0,9,0,9}$  (group C),  $AD^U, ADR^U, AD_{0,0}$  (group D),  $AD_{1,0}, AD_{0,9,0,1}, ADR^L$  (group E),  $AD_{0,1}, AD_{0,1,0,9}, AD^U$  (group F),  $AD_{1,0}, AD_{0,9,0,1}, ADR^L$  (group G) and  $AD_{0,1}, AD_{0,1,0,9}, SW$  (group H).

The sum of the powers for the groups of alternatives marked with indices 1 and 2 is the highest for  $AD_{1,0}, AD_{0,9,0,1}, SW$  (group A),  $AD_{0,1}, AD_{0,1,0,9}, SW$  (group B),

$CVM, AD_{1,1}, AD_{0,9,0,9}$  (group C),  $AD^U, ADR^U, SW$  (group D),  $AD_{1,0}, AD_{0,9,0,1}, ADR^L$  (groups E, G),  $AD_{0,1}, AD_{0,1,0,9}, AD^U$  (groups F, H) tests.

The sum of the powers for the groups of alternatives marked with indices 3 and 4 is the highest for  $ADL^U, |AD^U|, ADM^U$  (groups A, G),  $ADL^L, |AD^L|, ADM^L$  (groups B, H),  $AD^L, ADL, |AD|$  (group C),  $AD_{0,0}, LF, AD_{0,1,0,1}$  (group D),  $AD_{1,0}, AD_{0,9,0,1}, AD_{0,0}$  (group E),  $AD_{0,1}, AD_{0,1,0,9}, ADL^L$  (group F) tests.

The modified AD tests with test statistics (33), for the given alternative and similarity measure, achieves the highest empirical power in 28%, 22%, 0%, 34%, 53%, 31%, 41%, 19% of the considered cases related to groups A–H, respectively.

The observed dominance of particular modified AD tests within specific skewness-kurtosis regimes can be explained by the manner in which Bloom's EDF parameters  $(\alpha, \beta)$  control the relative weighting of discrepancies in the lower and upper tails of the distribution. Tests with  $\alpha > \beta$  place greater emphasis on the upper tail, which increases their sensitivity to right-skewed alternatives or distributions with heavy upper tails. This explains the strong performance of tests such as  $AD_{1,0}$  and  $AD_{0,9,0,1}$  for groups characterised by positive skewness (groups A and G).

Conversely, tests where  $\beta > \alpha$  emphasise deviations in the lower tail and therefore exhibit a higher power for left-skewed alternatives, as observed for  $AD_{0,1}$  and  $AD_{0,1,0,9}$  in groups B, F and H. For symmetric alternatives, the dominance of tests with  $\alpha \approx \beta$  reflects the fact that departures from normality occur simultaneously in both tails. In such cases, balanced tail-weighting strategies are more effective, which explains the strong performance of such tests as  $AD_{1,1}, AD_{0,9,0,9}$ , and the classical CVM test.

## 7. Real data examples

In this section, we present the application of the analysed tests in real datasets to illustrate their potentiality. For the real data examples, the distribution of each test statistic under the null hypothesis of normality was obtained through a Monte Carlo simulation using the same critical values as those computed in the power study for the corresponding sample size. The details related to examples I–VII are presented in Table 14.

**Table 14.** Real data examples with sources, sample size, skewness and excess kurtosis values

Ex.	Description	Source	n	$\gamma_1$	$\tilde{\gamma}_2$
I	Socio-economic data (percentage of males involved in agriculture as occupation) for 47 French-speaking provinces of Switzerland.	R package swiss[2]	47	-0.331	-0.793
II	Measurements of the diameter of timber in 31 felled black cherry trees. The diameter is measured at 4 ft 6 in above the ground.	trees[1]	31	0.526	-0.556
III	The effect of vitamin C on tooth length in guinea pigs. Each animal received one of the three different doses of vitamin C (0.5, 1, and 2 mg/day) by one of the two alternative delivery methods, i.e. orange juice or ascorbic acid.	ToothGrowth[1]	60	-0.146	-0.976
IV	Data extracted from the Motor Trend US magazine showing fuel consumption for 32 automobiles.	mtcars[1]	32	0.640	-0.200
V	Lawyers' ratings of state judges in the US Superior Court (sound written rulings).	USJudgeRatings[1]	43	-0.699	0.030
VI	Arrests per 100,000 residents for rape in each of the 50 US states in 1973.	USArrests[4]	50	0.777	0.202
VII	Average height for American women aged 30–39.	women[1]	15	0	-1.211

Source: authors' work.

When fitting the normal distribution to the data, we calculate the p-values for the analysed GoFTs based on  $10^5$  statistic values (see Table 15). The lowest p-values for all the analysed tests are in bold. The lowest p-values for the MAD tests are underlined. Non-normality is the most pronounced by the  $AD_{0,1}$  (examples I, III, V) and  $AD_{1,0}$  tests (examples II, IV). The lowest p-values for the MAD tests are observed for the  $AD_{1,0}$  and  $AD_{0,0}$  tests (examples VI, VII). The obtained results are consistent with the simulation results, according to which, if the real data are negatively skewed, the  $AD_{0,1}$  test is powerful, and if the real data are positively skewed, the  $AD_{1,0}$  is powerful, and if the real data are symmetric, the  $AD_{0,0}$  test is powerful.

**Table 15.** The p-values for the GoFTs related to examples I–VII

No.	GoFT	I	II	III	IV	V	VI	VII
1	$LF$	0.233	0.110	0.167	0.208	0.324	0.331	0.996
2	$CVM$	0.210	0.043	0.092	0.155	0.164	0.119	0.946
3	$SW$	0.190	0.089	0.107	0.123	0.096	<b>0.025</b>	0.727
4	$ AD^L $	0.489	0.499	0.495	0.497	0.165	0.495	0.513
5	$ AD^U $	0.490	0.240	0.489	0.279	0.490	0.122	<b>0.512</b>
6	$ AD $	0.328	0.456	0.544	0.246	0.365	0.150	0.987
7	$AD^L$	0.424	0.279	0.372	0.228	0.181	0.102	0.863
8	$AD^U$	0.215	0.072	0.083	0.104	0.146	0.093	0.904
9	$AD$	0.196	0.046	0.087	0.123	0.122	0.074	0.925
10	$\overline{AD}$	0.196	0.046	0.087	0.123	0.122	0.074	0.925
11	$\overline{\overline{AD}}$	0.196	0.046	0.087	0.123	0.122	0.074	0.925
12	$ADR^L$	0.194	0.040	0.103	0.164	0.125	0.079	0.919
13	$ADR^U$	0.213	0.062	0.084	0.110	0.147	0.094	0.918
14	$ADL^L$	0.437	0.208	0.293	0.291	0.111	0.150	0.781
15	$ADL^U$	0.302	0.271	0.337	0.138	0.229	0.062	0.779
16	$ADL$	0.424	0.279	0.372	0.228	0.181	0.102	0.863
17	$ADM^L$	0.268	0.100	0.183	0.225	<b>0.095</b>	0.086	0.851
18	$ADM^U$	0.259	0.152	0.179	0.103	0.171	0.045	0.848
19	$AD_{0,1}$	<u>0.173</u>	0.058	<u>0.082</u>	0.160	<u>0.095</u>	0.101	0.920
20	$AD_{1,0}$	0.225	<u>0.038</u>	0.093	<u>0.097</u>	0.161	<u>0.055</u>	0.920
21	$AD_{0,0}$	0.192	0.045	0.084	0.123	0.123	0.074	<u>0.916</u>
22	$AD_{1,1}$	0.201	0.048	0.090	0.123	0.122	0.073	0.933
23	$AD_{0.3,0.3}$	0.195	0.046	0.086	0.123	0.122	0.074	0.922
24	$AD_{3/8,3/8}$	0.195	0.046	0.086	0.123	0.122	0.074	0.923
25	$AD_{\frac{127}{400}, \frac{127}{400}}$	0.195	0.046	0.086	0.123	0.122	0.074	0.922
26	$AD_{0.1,0.1}$	0.193	0.046	0.084	0.123	0.123	0.074	0.918
27	$AD_{0.9,0.9}$	0.200	0.047	0.089	0.123	0.122	0.073	0.932
28	$AD_{0.9,0.1}$	0.219	0.039	0.091	0.102	0.152	0.058	0.921
29	$AD_{0.1,0.9}$	0.177	0.055	0.083	0.151	0.100	0.094	0.922

Source: authors' work.

## 8. Conclusions

The aims of the research presented in this article were fully achieved: the family of MAD tests was expanded, four new formulas for the EDF were proposed, a flexible family of alternatives was created, consisting of older and newer distributions, and the powers of 29 tests were compared focusing on the similarity measure of the alternative to the normal distribution.

Similarly to the modified L tests (Sulewski, 2021, 2022a), the parametrisation of the EDF based on Bloom's formula also influenced the power of the MAD test.

Tests  $|AD^L|$  (groups A, D, E, F, G),  $|AD^U|$  (B, D, E, F, H),  $|AD|$  (D, E, F, G, H),  $AD^L$  (D, E, F, H),  $ADL^L$  (A, D, E, F, G),  $ADL^U$  (B, D, E, F, H),  $ADM^L$  (A, D, E, G),  $ADM^U$  (D, F, H) and  $ADM$  (D) do not meet the basic assumptions, i.e. the power increases as the sample size increases and decreases as the similarity measure (36) increases.

The power of the  $\overline{AD}$  and  $\overline{AD}$  tests is the same for all the analysed cases.

The tests best detect samples from asymmetric distributions with positive excess kurtosis.

The power of the  $AD_{\alpha,\beta}$  ( $\alpha = \beta$ ;  $\alpha, \beta \leq 1$ ) tests is very similar for all groups of alternatives. It is noteworthy that the power of the  $AD_{\alpha,\beta}$  ( $\alpha \neq \beta$ ) tests for the given parameter values dominate in all of the analysed alternatives and similarity measures. The  $AD_{1,0}$  test is recommended for positively skewed alternatives and the  $AD_{0,1}$  test for negatively skewed alternatives. The  $AD_{1,1}$  and  $AD_{0,0}$  tests are recommended for symmetric alternatives.

The  $AD_{\alpha,\beta}$  test for the given alternative and similarity measure achieves high power in 53% of the cases in group E, 41% of the cases in group G, 34% of the cases in group D, 31% of the cases in group F and in 28% of the cases in group A. A result of less than 25% applies to groups B, C and H.

The analysis of real datasets has led to the conclusion that the MAD test is indeed effective.

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## Appendix

### Edgeworth series distribution

The PDF of the Edgeworth series (ES) with parameters  $\gamma_1$  and  $\bar{\gamma}_2$  is given by

$$f_{ES}(x; \gamma_1, \bar{\gamma}_2) = \phi(x; 0, 1) \left( 1 + \frac{1}{3!} \gamma_1 (x^3 - 3x) + \frac{1}{4!} \bar{\gamma}_2 (x^4 - 6x^2 + 3) \right) \quad (x \in R),$$

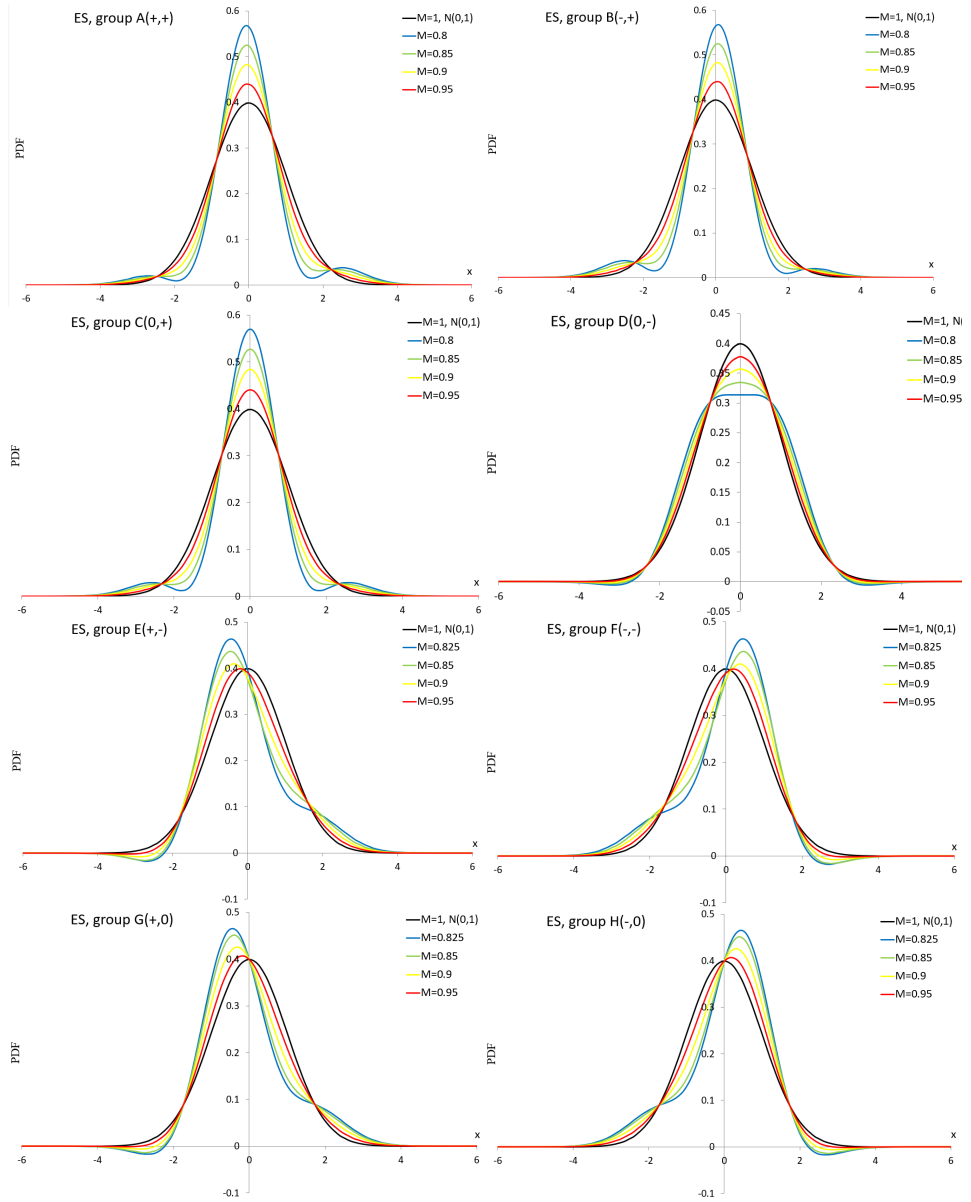
where  $\gamma_1, \in R, \bar{\gamma}_2 \geq -2$ .

**Table 1A.** Vectors of the ES parameter  $\theta$ , mean  $\mu_a$ , standard deviation  $\sigma_a$ , skewness  $\gamma_1$ , excess kurtosis  $\bar{\gamma}_2$  and similarity measure M. Groups O, A–H

Group	$\theta = (\gamma_1, \bar{\gamma}_2)$	$\mu_a$	$\sigma_a$	$\gamma_1$	$\bar{\gamma}_2$	$M(\theta; \mu, \sigma)$
O	(0,0)	0	1	0	0	$M(\theta; 0, 1) = 1$
A	0.4, 3.33	0	1	0.4	3.33	$M(\theta; 0, 1) = 0.8$
	0.3, 2.499	0	1	0.3	2.499	$M(\theta; 0, 1) = 0.85$
	0.2, 1.666	0	1	0.2	1.666	$M(\theta; 0, 1) = 0.9$
	0.1, 0.833	0	1	0.1	0.833	$M(\theta; 0, 1) = 0.95$
B	-0.4, 3.33	0	1	-0.4	3.33	$M(\theta; 0, 1) = 0.8$
	-0.3, 2.499	0	1	-0.3	2.499	$M(\theta; 0, 1) = 0.85$
	-0.2, 1.666	0	1	-0.2	1.666	$M(\theta; 0, 1) = 0.9$
	-0.1, 0.833	0	1	-0.1	0.833	$M(\theta; 0, 1) = 0.95$
C	0.3, 4.28	0	1	0	3.428	$M(\theta; 0, 1) = 0.8$
	0.2, 5.71	0	1	0	2.571	$M(\theta; 0, 1) = 0.85$
	0.1, 7.1	0	1	0	1.71	$M(\theta; 0, 1) = 0.9$
	0, 8.5	0	1	0	0.85	$M(\theta; 0, 1) = 0.95$
D	0, -3.428	0	1	0	-3.428	$M(\theta; 0, 1) = 0.8$
	0, -2.571	0	1	0	-2.571	$M(\theta; 0, 1) = 0.85$
	0, -1.71	0	1	0	-1.71	$M(\theta; 0, 1) = 0.9$
	0, -0.85	0	1	0	-0.85	$M(\theta; 0, 1) = 0.95$
E	1.39, -0.067	0	1	1.39	-0.067	$M(\theta; 0, 1) = 0.825$
	1.175, -0.46	0	1	1.175	-0.46	$M(\theta; 0, 1) = 0.85$
	0.775, -0.408	0	1	0.775	-0.408	$M(\theta; 0, 1) = 0.9$
	0.39, -0.15	0	1	0.39	-0.15	$M(\theta; 0, 1) = 0.95$
F	-1.39, -0.067	0	1	-1.39	-0.067	$M(\theta; 0, 1) = 0.825$
	-1.175, -0.46	0	1	-1.175	-0.46	$M(\theta; 0, 1) = 0.85$
	-0.775, -0.408	0	1	-0.775	-0.408	$M(\theta; 0, 1) = 0.9$
	-0.39, -0.15	0	1	-0.39	-0.15	$M(\theta; 0, 1) = 0.95$
G	1.391, 0	0	1	1.391	0	$M(\theta; 0, 1) = 0.825$
	1.19, 0	0	1	1.19	0	$M(\theta; 0, 1) = 0.85$
	0.795, 0	0	1	0.795	0	$M(\theta; 0, 1) = 0.9$
	0.4, 0	0	1	0.4	0	$M(\theta; 0, 1) = 0.95$
H	-1.391, 0	0	1	-1.391	0	$M(\theta; 0, 1) = 0.825$
	-1.19, 0	0	1	-1.19	0	$M(\theta; 0, 1) = 0.85$
	-0.795, 0	0	1	-0.795	0	$M(\theta; 0, 1) = 0.9$
	-0.4, 0	0	1	-0.4	0	$M(\theta; 0, 1) = 0.95$

Source: authors' work.

**Figure 1A.** PDF curves of the ES distribution for parameter values presented in Table 1A



Source: authors' work.

### Pearson distribution

Let  $a = \frac{2\bar{\gamma}_2 - 3\gamma_1^2}{10\bar{\gamma}_2 - 5\gamma_1^2 + 12}$ ,  $b = \frac{|\gamma_1|(\bar{\gamma}_2 + 6)}{10\bar{\gamma}_2 - 5\gamma_1^2 + 12}$ ,  $c = \frac{4\bar{\gamma}_2 - 3\gamma_1^2 + 12}{10\bar{\gamma}_2 - 5\gamma_1^2 + 12}$ ,  $\Delta = b^2 - 4ac$ , then the PDF of the Pearson (P) distribution is given by

$$f_P(x; \gamma_1, \bar{\gamma}_2) = \begin{cases} \frac{\exp\left[\frac{2ab - b}{a(2ax + b)}\right]}{C_1(2ax + b)^{1/a}} & \Delta = 0 \\ \frac{\exp\left[\frac{b - 2ab}{a\sqrt{4ac - b^2}} \tan^{-1}\left(\frac{2ax + b}{\sqrt{4ac - b^2}}\right)\right]}{C_2(ax^2 + bx + c)^{1/(2a)}} & \Delta < 0 \\ \frac{\left(\frac{2ax + b - \sqrt{b^2 - 4ac}}{2ax + b + \sqrt{b^2 - 4ac}}\right)^{\frac{b - 2ab}{2a\sqrt{b^2 - 4ac}}}}{C_3(ax^2 + bx + c)^{1/(2a)}} & \Delta > 0 \end{cases}$$

where  $x \in R$ ,  $\gamma_1 \in R$ ,  $\bar{\gamma}_2 \geq -2$  and  $C_1, C_2, C_3$  are normalising constants defined as

$$C_1 = \int_{-\infty}^{\infty} \frac{\exp\left[\frac{2ab - b}{a(2ax + b)}\right]}{(2ax + b)^{\frac{1}{a}}} dx,$$

$$C_2 = \int_{-\infty}^{\infty} \frac{\exp\left[\frac{b - 2ab}{a\sqrt{4ac - b^2}} \tan^{-1}\left(\frac{2ax + b}{\sqrt{4ac - b^2}}\right)\right]}{(ax^2 + bx + c)^{\frac{1}{2a}}} dx,$$

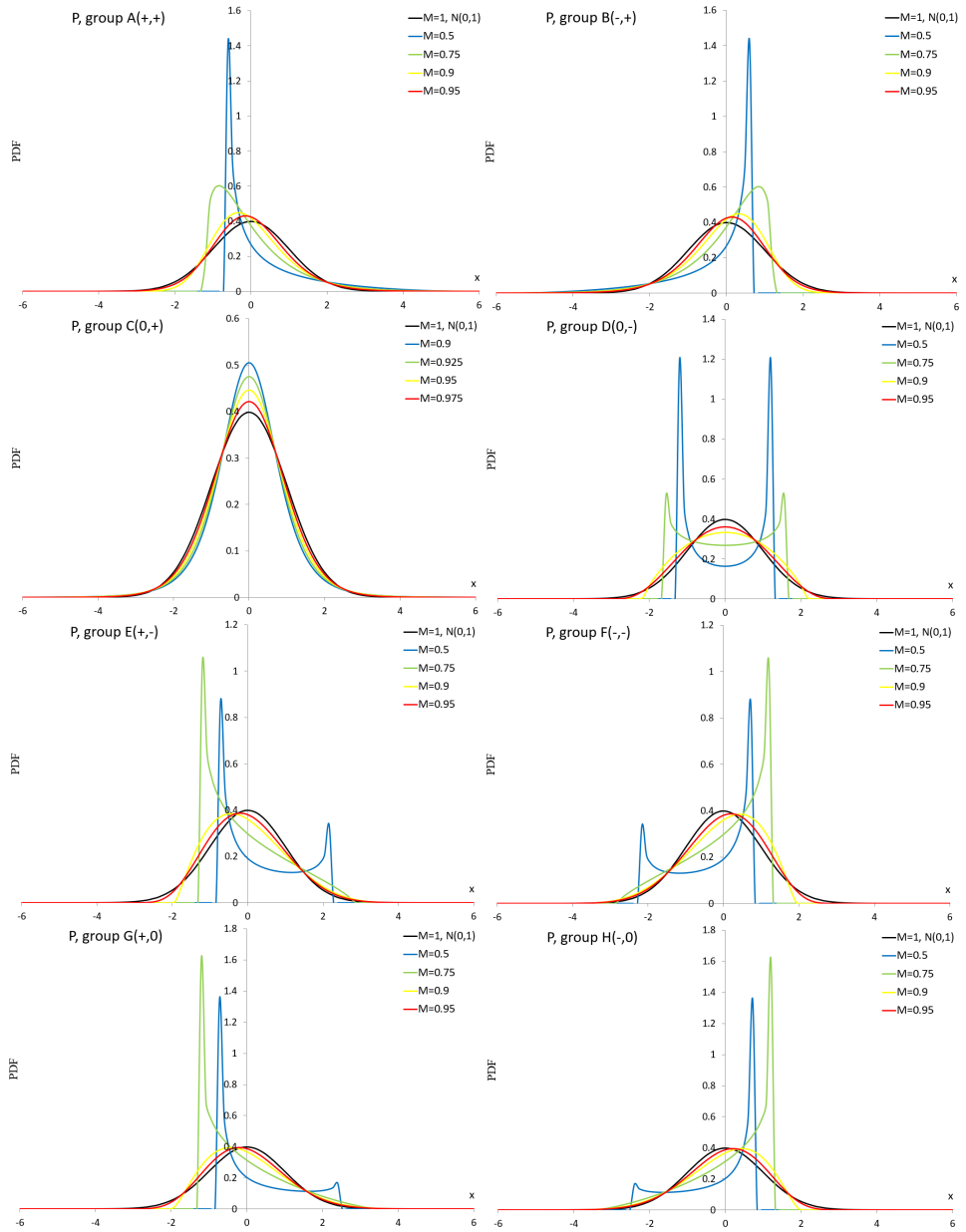
$$C_3 = \int_{-\infty}^{\infty} \frac{\left(\frac{2ax + b - \sqrt{\Delta}}{2ax + b + \sqrt{\Delta}}\right)^{\frac{b - 2ab}{2a\sqrt{\Delta}}}}{C_8(ax^2 + bx + c)^{1/(2a)}} dx.$$

**Table 2A.** Vectors of the P parameter  $\theta$ , mean  $\mu_a$ , standard deviation  $\sigma_a$ , skewness  $\gamma_1$ , excess kurtosis  $\bar{\gamma}_2$  and similarity measure M. Groups O, A-H

Group	$\theta = (\gamma_1, \bar{\gamma}_2)$	$\mu_a$	$\sigma_a$	$\gamma_1$	$\bar{\gamma}_2$	$M(\theta; \mu, \sigma)$
O	(0,0)	0	1	0	0	$M(\theta; 0,1) = 1$
A	(2.04,4.1)	0	1	2.04	4.1	$M(\theta; 0,1) = 0.5$
	(1.62,3.845)	0	1	1.62	3.845	$M(\theta; 0,1) = 0.75$
	(0.9,2)	0	1	0.9	2	$M(\theta; 0,1) = 0.9$
	(0.4,0.94)	0	1	0.4	0.94	$M(\theta; 0,1) = 0.95$
B	(-2.04,4.1)	0	1	-2.04	4.1	$M(\theta; 0,1) = 0.5$
	(-1.62,3.845)	0	1	-1.62	3.845	$M(\theta; 0,1) = 0.75$
	(-0.9,2)	0	1	-0.9	2	$M(\theta; 0,1) = 0.9$
	(-0.4,0.94)	0	1	-0.4	0.94	$M(\theta; 0,1) = 0.95$
C	(0,11.2)	0	1	0	11.2	$M(\theta; 0,1) = 0.9$
	(0,3.65)	0	1	0	3.65	$M(\theta; 0,1) = 0.925$
	(0,1.521)	0	1	0	1.521	$M(\theta; 0,1) = 0.95$
	(0,0.55)	0	1	0	0.55	$M(\theta; 0,1) = 0.975$
D	(0,-1.695)	0	1	0	-1.695	$M(\theta; 0,1) = 0.5$
	(0,-1.315)	0	1	0	-1.315	$M(\theta; 0,1) = 0.75$
	(0,-0.89)	0	1	0	-0.89	$M(\theta; 0,1) = 0.9$
	(0,-0.588)	0	1	0	-0.588	$M(\theta; 0,1) = 0.95$
E	(0.985,-0.5)	0	1	0.985	-0.5	$M(\theta; 0,1) = 0.5$
	(0.715,-0.475)	0	1	0.715	-0.475	$M(\theta; 0,1) = 0.75$
	(0.515,-0.2)	0	1	0.515	-0.2	$M(\theta; 0,1) = 0.9$
	(0.315,-0.16)	0	1	0.315	-0.16	$M(\theta; 0,1) = 0.95$
F	(-0.985,-0.5)	0	1	-0.985	-0.5	$M(\theta; 0,1) = 0.5$
	(-0.715,-0.475)	0	1	-0.715	-0.475	$M(\theta; 0,1) = 0.75$
	(-0.515,-0.2)	0	1	-0.515	-0.2	$M(\theta; 0,1) = 0.9$
	(-0.315,-0.16)	0	1	-0.315	-0.16	$M(\theta; 0,1) = 0.95$
G	(1.164,0)	0	1	1.164	0	$M(\theta; 0,1) = 0.5$
	(0.879,0)	0	1	0.879	0	$M(\theta; 0,1) = 0.75$
	(0.578,0)	0	1	0.578	0	$M(\theta; 0,1) = 0.9$
	(0.354,0)	0	1	0.354	0	$M(\theta; 0,1) = 0.95$
H	(-1.164,0)	0	1	-1.164	0	$M(\theta; 0,1) = 0.5$
	(-0.879,0)	0	1	-0.879	0	$M(\theta; 0,1) = 0.75$
	(-0.578,0)	0	1	-0.578	0	$M(\theta; 0,1) = 0.9$
	(-0.354,0)	0	1	-0.354	0	$M(\theta; 0,1) = 0.95$

Source: authors' work.

**Figure 2A.** PDF curves of the P distribution for the parameter values presented in Table 2A



Source: authors' work.

### Normal mixture distribution

The PDF of the normal mixture (NM) distribution is given by

$$f_{NM}(x; \boldsymbol{\theta}) = \omega\phi(x; \mu_1, \sigma_1) + (1 - \omega)\phi(x; \mu_2, \sigma_2) \quad (x \in R),$$

where  $\boldsymbol{\theta} = (\mu_1, \sigma_1, \mu_2, \sigma_2, \omega)$  and  $\mu_1, \mu_2 \in R, \sigma_1, \sigma_2 > 0, \omega \in [0,1]$ .

Special cases of the NM distribution are:

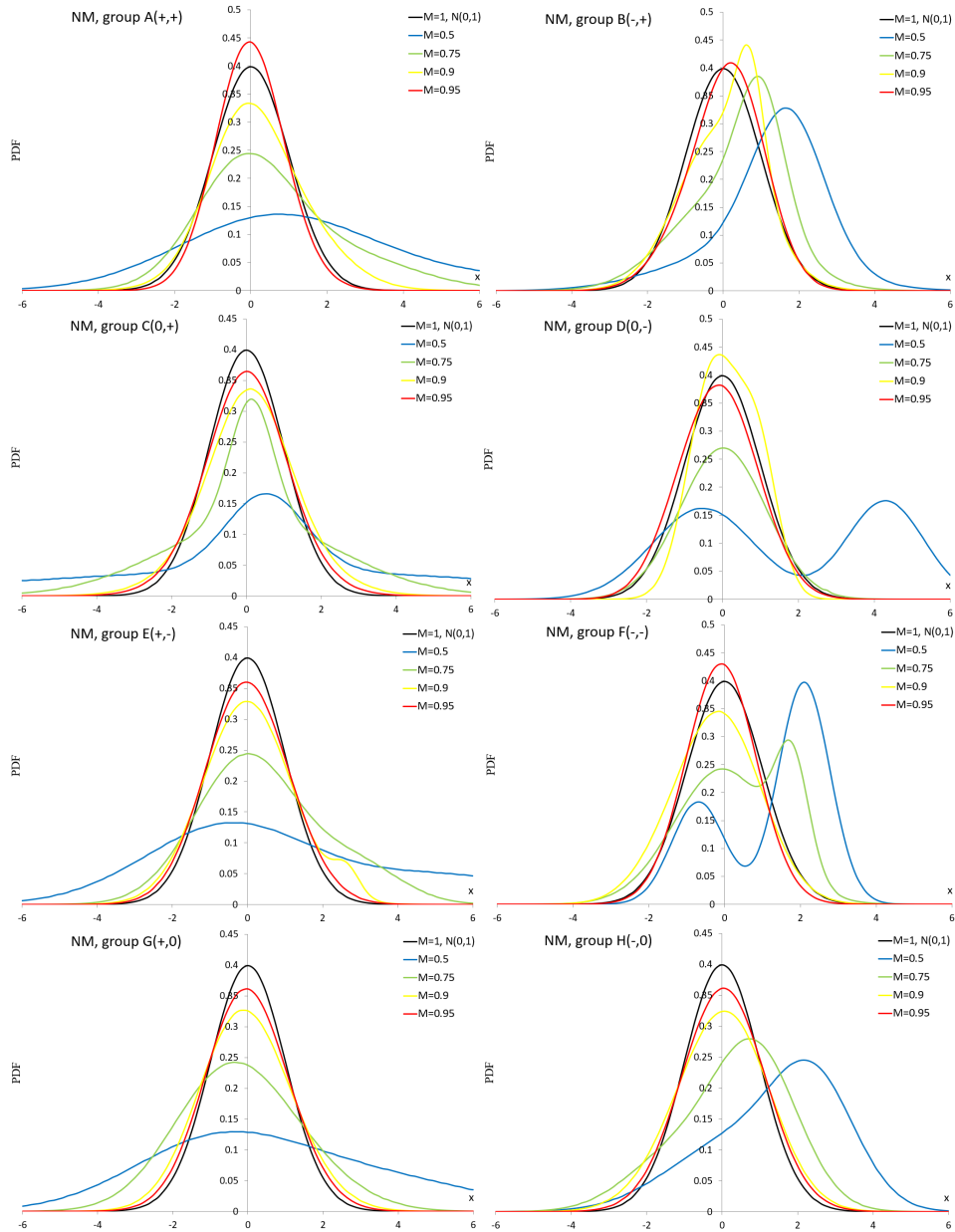
- normal  $N(\mu_1, \sigma_1)$  for  $\omega = 1, N(\mu_2, \sigma_2)$  for  $\omega = 0$ ;
- location contaminated normal (LCN)  $f_{LCM}(x; \mu_1, \omega) = f_{NM}(x; \mu_1, 1, 0, 1, \omega)$ ;
- scale contaminated normal (SCN)  $f_{SCN}(x; \sigma_1, \omega) = f_{NM}(x; 0, \sigma_1, 0, 1, \omega)$ .

**Table 3A.** Vectors of the NM parameter  $\boldsymbol{\theta}$ , mean  $\mu_a$ , standard deviation  $\sigma_a$ , skewness  $\gamma_1$ , excess kurtosis  $\tilde{\gamma}_2$  and similarity measure M. Groups O, A–H

Group	$\boldsymbol{\theta} = (\mu_1, \sigma_1, \mu_2, \sigma_2, \omega)$	$\mu_a$	$\sigma_a$	$\gamma_1$	$\tilde{\gamma}_2$	$M(\boldsymbol{\theta}; \mu, \sigma)$
O	$(\mu_1, \sigma_1, \mu_2, \sigma_2, 1)$	0	1	0	0	$M(\boldsymbol{\theta}; \mu_1, \sigma_1) = 1$
	$(\mu_1, \sigma_1, \mu_2, \sigma_2, 0)$	0	1	0	0	$M(\boldsymbol{\theta}; \mu_2, \sigma_2) = 1$
A	0.572,2.472,5.614,3.454,0.787	1.646	3.408	0.685	0.755	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	-0.215,1.254,1.979,1.99,0.639	0.577	1.883	0.645	0.502	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	0.497,1.376,-0.268,0.884,0.612	0.2	1.265	0.287	0.249	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	-0.098,0.857,0.31,1.007,0.767	-0.003	0.911	0.09	0.099	$M(\boldsymbol{\theta}; 0,1) = 0.95$
B	0.502,2.019,1.708,0.953,0.36	1.274	1.544	-0.748	1.502	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	0.06,1.437,1.004,0.609,0.634	0.406	1.285	-0.5	0.499	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	0.709,0.368,-0.072,1.115,0.193	0.079	1.06	-0.301	0.15	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	0.32,0.855,-0.873,0.923,0.782	0.06	1	-0.238	0.1	$M(\boldsymbol{\theta}; 0,1) = 0.95$
C	0.519,6.599,0.519,1.058,0.665	0.519	5.416	0	1.398	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	0.137,0.581,0.137,2.391,0.294	0.137	2.034	0	1.054	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	0.1,0.988,0.1,1.543,0.532	0.1	1.278	0	0.554	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	0.007,0.942,0.007,1.299,0.494	0.007	1.137	0	0.289	$M(\boldsymbol{\theta}; 0,1) = 0.95$
D	-0.511,1.353,4.293,1.021,0.551	1.645	2.681	0	-1.28	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	2.707,0.013,0.017,1.125,0.238	0.657	1.509	0	-1.001	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	1.243,0.621,-0.39,0.811,0.347	0.111	1.09	0	-0.63	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	-1.112,0.794,0.023,0.974,0.13	0	0.897	0	-0.329	$M(\boldsymbol{\theta}; 0,1) = 0.95$
E	-0.475,2.225,3.318,2.427,0.721	1.141	3.457	0.5	-0.204	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	-0.019,1.369,2.979,1.15,0.829	0.494	1.748	0.339	-0.1	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	2.635,0.35,-0.015,1.166,0.038	0.086	1.253	0.137	-0.075	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	1.091,0.969,-0.111,1.056,0.1	0.009	1.108	0.05	-0.01	$M(\boldsymbol{\theta}; 0,1) = 0.95$
F	-0.692,0.705,2.1,0.679,0.324	1.195	1.476	-0.542	-0.852	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	-0.055,1.277,1.781,0.443,0.775	0.358	1.377	-0.3	-0.5	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	-0.09,1.08,-1.581,0.92,0.9	-0.239	1.155	-0.071	-0.042	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	0.386,0.845,-0.145,0.918,0.1	-0.092	0.925	-0.01	-0.011	$M(\boldsymbol{\theta}; 0,1) = 0.95$
G	2.686,3.099,-0.964,2.217,0.471	0.755	3.232	0.4	0	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	-0.56,1.465,1.411,1.45,0.8	-0.166	1.661	0.151	0	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	-0.286,1.114,0.984,1.105,0.801	-0.033	1.222	0.101	0	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	-0.1,1.063,1.261,0.94,0.936	-0.013	1.106	0.053	0	$M(\boldsymbol{\theta}; 0,1) = 0.95$
H	2.425,1.101,0.272,1.693,0.526	1.404	1.775	-0.499	0	$M(\boldsymbol{\theta}; 0,1) = 0.5$
	0.864,1.125,-1.339,1.241,0.735	0.28	1.511	-0.386	0	$M(\boldsymbol{\theta}; 0,1) = 0.75$
	0.429,1.078,-0.364,1.228,0.434	-0.02	1.23	-0.1	0	$M(\boldsymbol{\theta}; 0,1) = 0.9$
	0.108,1.088,-0.524,1.073,0.879	0.032	1.106	-0.01	0	$M(\boldsymbol{\theta}; 0,1) = 0.95$

Source: authors' work.

**Figure 3A.** PDF curves of the NM distribution for parameter values presented in Table 3A



Source: authors' work.

### Normal distribution with plasticising component

The PDF of the normal distribution with plasticising component (NDPC) is given by

$$f_{NDPC}(x; \theta) = \omega \phi(x; \mu_1, \sigma_1) + (1 - \omega) \frac{c_2}{\sigma_2} \left| \frac{x - \mu_2}{\sigma_2} \right|^{c_2 - 1} \phi \left( \left| \frac{x - \mu_2}{\sigma_2} \right|^{c_2}; 0, 1 \right) \quad (x \in R),$$

where  $\theta = (\mu_1, \sigma_1, \mu_2, \sigma_2, c_2, \omega)$  and  $\mu_1, \mu_2 \in R, \sigma_1, \sigma_2 > 0, c_2 \geq 1, \omega \in [0, 1]$ .

Special cases of the NDPC distribution are:

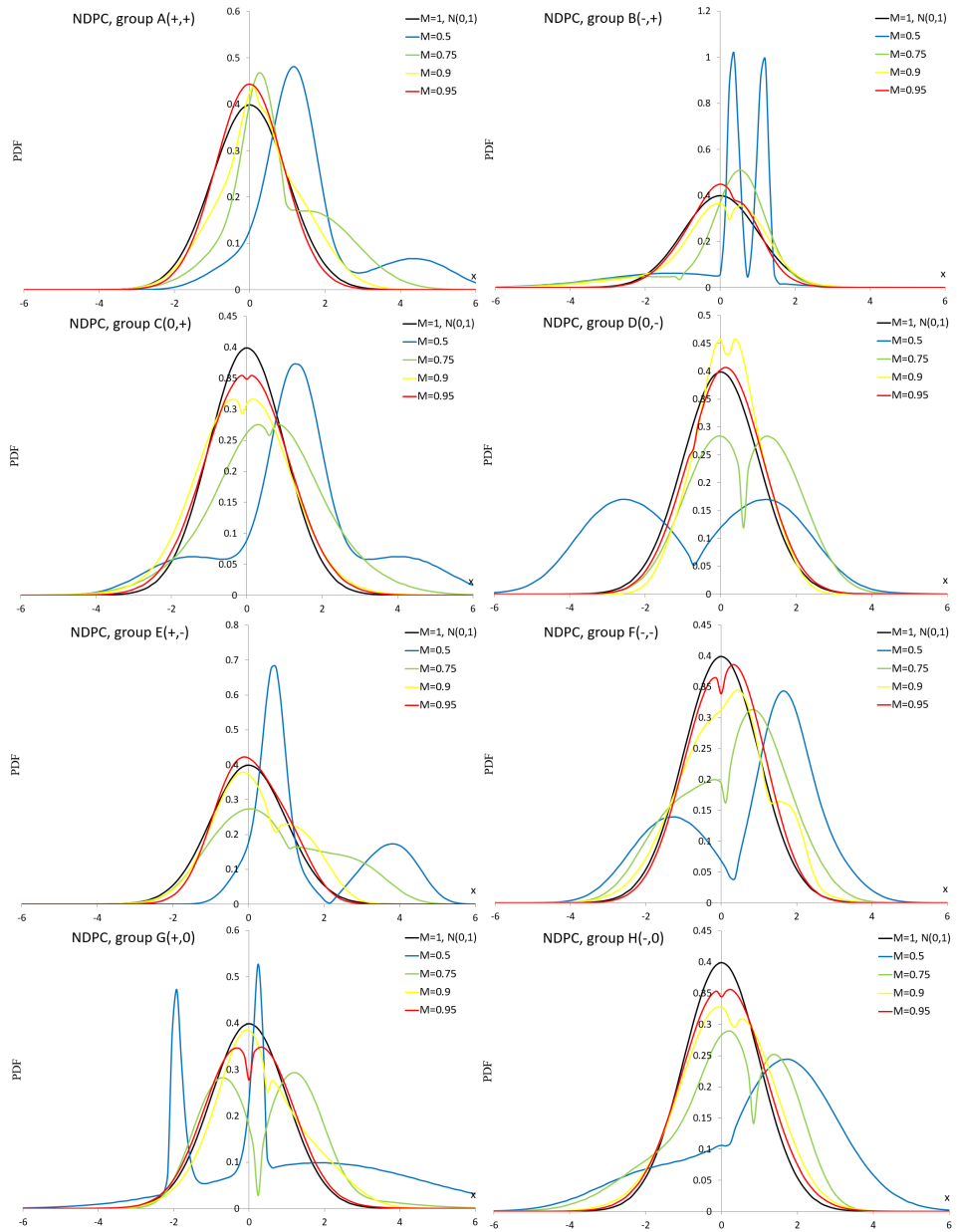
- $N(\mu_1, \sigma_1)$  for  $\omega = 1$  and  $N(\mu_2, \sigma_2)$  for  $c_2 = 1, \omega = 0$ ;
- plasticising component (PC)  $f_{PC}(x; \mu_2, \sigma_2, c_2)$  for  $\omega = 0$ .

**Table 4A.** Vectors of the NDPC parameter  $\theta$ , mean  $\mu_a$ , standard deviation  $\sigma_a$ , skewness  $\gamma_1$ , excess kurtosis  $\bar{\gamma}_2$  and similarity measure M. Groups O, A–H

Group	$\theta = (\mu_1, \sigma_1, \mu_2, \sigma_2, c_2, \omega)$	$\mu_a$	$\sigma_a$	$\gamma_1$	$\bar{\gamma}_2$	$M(\theta; \mu, \sigma)$
O	$\mu_1, \sigma_1, \mu_2, \sigma_2, c_2, 1$	0	1	0	0	$M(\theta; \mu_1, \sigma_1) = 1$
	$\mu_1, \sigma_1, \mu_2, \sigma_2, 1, 0$	0	1	0	0	$M(\theta; \mu_2, \sigma_2) = 1$
A	1.194,0.601,2.186,2.592,2,0.666	1.526	1.5	1.002	1.001	$M(\theta; 0, 1) = 0.5$
	0.265,0.415,0.996,1.541,1.16,0.313	0.767	1.288	0.426	0.152	$M(\theta; 0, 1) = 0.75$
	0.173,0.358,0.289,1.268,1.132,0.198	0.266	1.104	0.056	0.071	$M(\theta; 0, 1) = 0.9$
	0.047,1.02,-0.014,0.872,1,0.214	-0.001	0.906	0.012	0.06	$M(\theta; 0, 1) = 0.95$
B	-1.321,1.842,0.741,0.459,2.56,0.287	0.15	1.4	-1.764	3.3	$M(\theta; 0, 1) = 0.5$
	0.539,0.632,-1.078,2.061,1.174,0.741	0.12	1.34	-1.499	2.986	$M(\theta; 0, 1) = 0.75$
	-0.966,1.824,0.259,0.889,1.1,0.26	-0.059	1.305	-0.899	1.999	$M(\theta; 0, 1) = 0.9$
	-0.099,0.938,0.399,0.646,1.204,0.831	-0.015	0.911	-0.125	0.036	$M(\theta; 0, 1) = 0.95$
C	1.308,0.656,1.308,3.261,2,0.613	1.308	1.884	0	0.504	$M(\theta; 0, 1) = 0.5$
	0.571,1.023,0.571,1.962,1.15,0.505	0.571	1.508	0	0.325	$M(\theta; 0, 1) = 0.75$
	-0.097,1.332,-0.097,1.058,1.1,0.614	-0.097	1.223	0	0.101	$M(\theta; 0, 1) = 0.9$
	0.003,1.135,0.003,0.95,1.05,0.874	0.003	1.112	0	0.026	$M(\theta; 0, 1) = 0.95$
D	-0.692,2.203,-0.692,2.544,1.759,0.25	-0.692	2.265	0	-1	$M(\theta; 0, 1) = 0.5$
	0.323,1.312,0.605,1.335,1.2,0.01	0.602	1.266	0	-0.587	$M(\theta; 0, 1) = 0.75$
	0.179,0.494,0.179,1.163,1.465,0.443	0.179	0.862	0	-0.202	$M(\theta; 0, 1) = 0.9$
	0.195,0.96,-0.719,0.858,1.109,0.918	0.12	0.983	0	-0.05	$M(\theta; 0, 1) = 0.95$
E	0.675,0.284,2.122,1.968,2.104,0.374	1.581	1.565	0.749	-0.849	$M(\theta; 0, 1) = 0.5$
	0.423,1.032,1.058,2.077,1.815,0.494	0.744	1.544	0.311	-0.667	$M(\theta; 0, 1) = 0.75$
	-0.134,0.993,0.671,1.211,1.479,0.583	0.202	1.115	0.115	-0.4	$M(\theta; 0, 1) = 0.9$
	1.081,0.621,-0.216,0.755,1,0.24	0.095	0.912	0.1	-0.298	$M(\theta; 0, 1) = 0.95$
F	1.609,0.59,0.322,2.194,1.609,0.309	0.72	1.784	-0.491	-0.728	$M(\theta; 0, 1) = 0.5$
	0.617,0.737,0.129,1.752,1.465,0.332	0.291	1.395	-0.239	-0.526	$M(\theta; 0, 1) = 0.75$
	-0.046,1.156,1.261,0.799,1.87,0.876	0.116	1.191	-0.1	-0.2	$M(\theta; 0, 1) = 0.9$
	0.155,0.882,0.019,1.184,1.175,0.581	0.098	0.995	-0.05	-0.188	$M(\theta; 0, 1) = 0.95$
G	1.88,2.736,-0.848,1.122,6.437,0.679	1.005	2.656	0.524	0	$M(\theta; 0, 1) = 0.5$
	2.419,1.56,0.237,1.384,1.476,0.074	0.398	1.409	0.35	0	$M(\theta; 0, 1) = 0.75$
	0.055,0.702,0.474,1.586,1.328,0.473	0.276	1.191	0.31	0	$M(\theta; 0, 1) = 0.9$
	0.212,1.443,-0.012,1.057,1.088,0.1	0.01	1.079	0.05	0	$M(\theta; 0, 1) = 0.95$
H	1.642,1.247,0.202,2.681,1.428,0.554	1	2.018	-0.594	0	$M(\theta; 0, 1) = 0.5$
	-1.246,1.326,0.858,1.103,1.242,0.313	0.2	1.496	-0.5	0	$M(\theta; 0, 1) = 0.75$
	-0.115,1.286,0.306,1.091,1.093,0.465	0.11	1.189	-0.1	0	$M(\theta; 0, 1) = 0.9$
	0.084,0.949,0.03,1.214,1.047,0.423	0.053	1.098	-0.016	0	$M(\theta; 0, 1) = 0.95$

Source: authors' work.

**Figure 4A.** PDF curves of the NDPC for parameter values presented in Table 4A



Source: authors' work.

### Plasticising component mixture distribution

The PDF of the plasticising component mixture distribution (PCM) is given by

$$f_{PCM}(x; \theta) = \omega f_{PC}(x; \mu_1, \sigma_1, c_1) + (1 - \omega) f_{PC}(x; \mu_2, \sigma_2, c_2) \quad (x \in R),$$

where  $f_{PC}(x; \mu, \sigma, c) = \frac{c}{\sigma} \left| \frac{x-\mu}{\sigma} \right|^{c-1} \phi \left( \left| \frac{x-\mu}{\sigma} \right|^c; 0, 1 \right) \quad (x \in R)$

and  $\theta = (\mu_1, \sigma_1, c_1, \mu_2, \sigma_2, c_2, \omega)$ ,  $\mu_1, \mu_2 \in R$ ,  $\sigma_1, \sigma_2 > 0$ ,  $c_1, c_2 \geq 1$ ,  $\omega \in [0, 1]$ .

Special cases of the PCM distribution are:

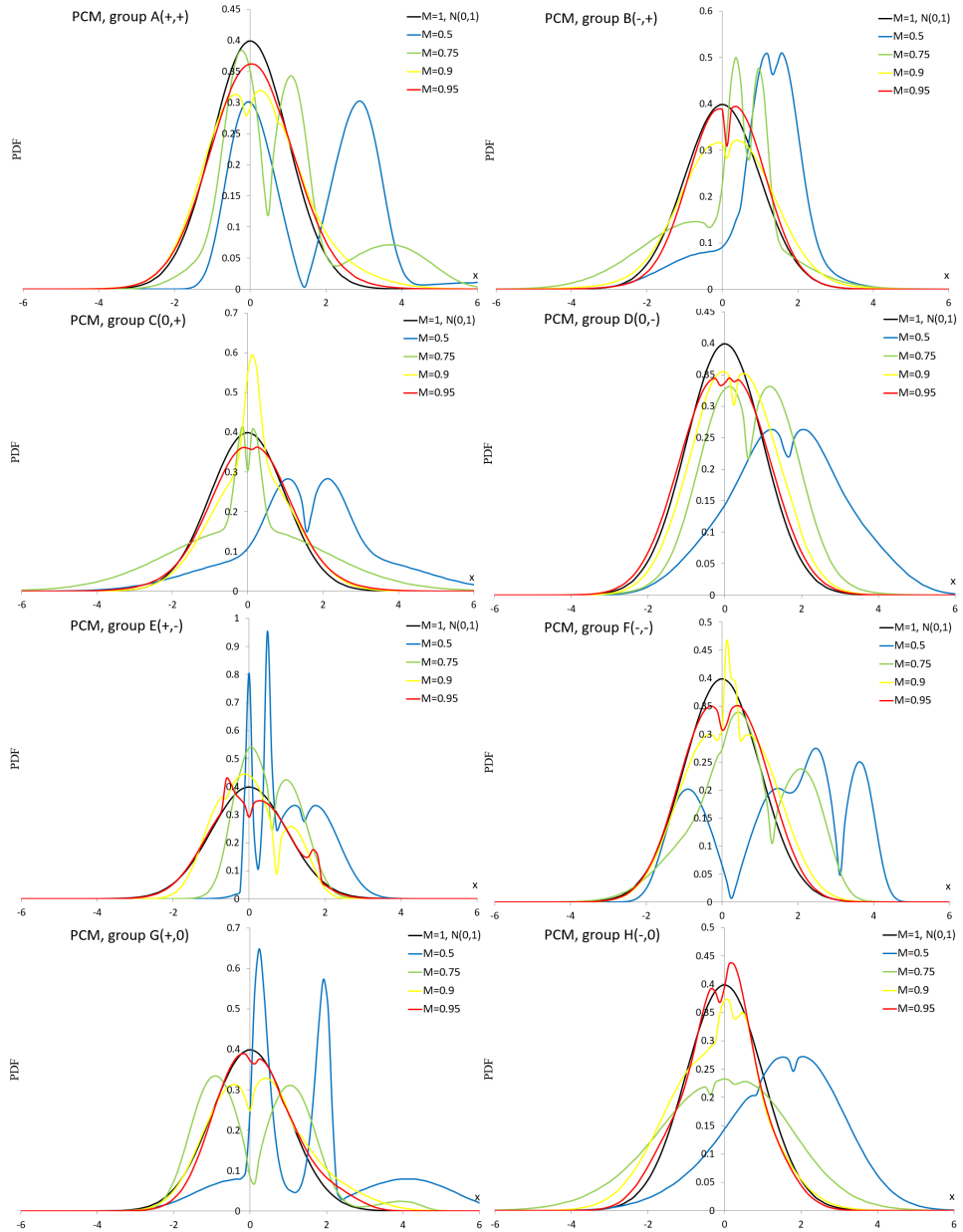
- $N(\mu_1, \sigma_1)$  for  $c_1 = 1, \omega = 1$ ;  $N(\mu_2, \sigma_2)$  for  $c_2 = 1, \omega = 0$ ;
- plasticising component  $PC(\mu_1, \sigma_1, c_1), PC(\mu_2, \sigma_2, c_2)$  for  $\omega = 1, \omega = 0$ , respectively.

**Table 5A.** Vectors of the PCM parameter  $\theta$ , mean  $\mu_a$ , standard deviation  $\sigma_a$ , skewness  $\gamma_1$ , excess kurtosis  $\bar{\gamma}_2$  and similarity measure  $M$ . Groups O, A–H

Group	$\theta = (\mu_1, \sigma_1, c_1, \mu_2, \sigma_2, c_2, \omega)$	$\mu_a$	$\sigma_a$	$\gamma_1$	$\bar{\gamma}_2$	$M(\theta; \mu, \sigma)$
O	$\mu_1, \sigma_1, 1, \mu_2, \sigma_2, 1$	0	1	0	0	$M(\theta; \mu_1, \sigma_1) = 1$
	$\mu_1, \sigma_1, c_1, \mu_2, \sigma_2, 1, 0$	0	1	0	0	$M(\theta; \mu_2, \sigma_2) = 1$
A	1.415,1.684,2.194,1.1252,5.474,2.331,0.9	2.399	3.622	2.647	7.663	$M(\theta; 0,1) = 0.5$
	0.444,0.899,1.602,1.653,2.506,1.876,0.64	0.879	1.604	0.913	0.412	$M(\theta; 0,1) = 0.75$
	-0.076,1.056,1.1,1.0,701,1.646,1.095,0.71	0.149	1.268	0.374	0.374	$M(\theta; 0,1) = 0.9$
	0.026,1.078,1.001,0.701,1.646,1.174,0.95	0.06	1.117	0.099	0.148	$M(\theta; 0,1) = 0.95$
B	1.366,0.572,1.11,0.502,1.669,1.253,0.658	1.071	1.099	-0.978	1.565	$M(\theta; 0,1) = 0.5$
	0.67,0.425,1.576,-0.323,1.696,1.05,0.349	0.024	1.444	-0.569	0.606	$M(\theta; 0,1) = 0.75$
	-0.204,2.209,1.205,0.133,1.139,1.05,0.076	0.107	1.224	-0.122	0.457	$M(\theta; 0,1) = 0.9$
	0.121,0.936,1.05,-0.17,1.917,1.411,0.95	0.106	0.982	-0.1	0.204	$M(\theta; 0,1) = 0.95$
C	1.597,2.518,1.263,1.596,0.856,1.285,0.526	1.597	1.797	0	0.601	$M(\theta; 0,1) = 0.5$
	0.012,0.274,1.256,0.012,2.046,1.01,0.183	0.012	1.846	0	0.598	$M(\theta; 0,1) = 0.75$
	0.127,1.089,1.01,0.127,0.183,1.01,0.863	0.127	1.01	0	0.401	$M(\theta; 0,1) = 0.9$
	0.075,0.973,1.01,0.075,1.964,1.362,0.867	0.075	1.119	0	0.387	$M(\theta; 0,1) = 0.95$
D	1.631,0.893,1.05,1.632,2.104,1.554,0.498	1.632	1.488	0	-0.268	$M(\theta; 0,1) = 0.5$
	0.639,1.576,1.167,0.64,1.085,1.199,0.163	0.64	1.12	0	-0.251	$M(\theta; 0,1) = 0.75$
	0.666,1.123,4.041,0.233,1.069,1.05,0.01	0.237	1.052	0	-0.198	$M(\theta; 0,1) = 0.9$
	0.225,1.087,1.05,-0.067,1.094,1.05,0.233	0.001	1.081	0	-0.18	$M(\theta; 0,1) = 0.95$
E	1.472,0.782,1.11,0.236,0.291,3.203,0.692	1.091	0.861	0.38	-0.8	$M(\theta; 0,1) = 0.5$
	-0.196,0.341,1.064,0.613,0.758,1.204,0.153	0.489	0.734	0.201	-0.7	$M(\theta; 0,1) = 0.75$
	0.722,0.703,1.304,-0.57,0.598,1.05,0.455	0.018	0.893	0.179	-0.617	$M(\theta; 0,1) = 0.9$
	0.584,1.171,9.804,-0.016,1.024,1.076,0.05	0.014	1.013	0.028	-0.351	$M(\theta; 0,1) = 0.95$
F	0.261,1.419,1.909,3.099,0.744,1.567,0.57	1.481	1.757	-0.3	-1.107	$M(\theta; 0,1) = 0.5$
	0.037,1.295,1.076,1.316,1.171,1.654,0.485	0.696	1.326	-0.204	-0.4	$M(\theta; 0,1) = 0.75$
	0.201,0.121,1.573,0.184,1.177,1.161,0.066	0.185	1.087	-0.003	-0.331	$M(\theta; 0,1) = 0.9$
	0.049,1.063,1.088,1.392,0.511,1.05,0.99	0.062	1.038	-0.008	-0.328	$M(\theta; 0,1) = 0.95$
G	1.088,0.894,3.782,1.969,2.71,1.792,0.55	1.484	1.793	0.6	0	$M(\theta; 0,1) = 0.5$
	1.515,2.553,3.55,0.07,1.328,1.619,0.07	0.171	1.359	0.501	0	$M(\theta; 0,1) = 0.75$
	-0.034,1.072,1.159,1.146,1.51,1.301,0.756	0.254	1.238	0.401	0	$M(\theta; 0,1) = 0.9$
	0.825,1.615,1.868,0.067,0.934,1.05,0.141	0.174	1.044	0.336	0	$M(\theta; 0,1) = 0.95$
H	0.816,1.867,1.24,1.787,1.272,1.05,0.278	1.517	1.475	-0.302	0	$M(\theta; 0,1) = 0.5$
	-0.364,1.889,1.057,0.29,1.413,1.05,0.527	-0.055	1.682	-0.154	0	$M(\theta; 0,1) = 0.75$
	0.286,0.405,1.27,-0.263,1.261,1.05,0.112	-0.202	1.188	-0.128	0	$M(\theta; 0,1) = 0.9$
	-0.153,1.344,1.349,-0.024,0.539,1.05,0.565	-0.097	1	-0.12	0	$M(\theta; 0,1) = 0.95$

Source: authors' work.

**Figure 5A.** PDF curves of the PCM distribution for parameter values presented in Table 5A



Source: authors' work.

# Demand for ESG data. Evidence from the Polish banking sector

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**Abstract.** Growing ESG (Environmental, Social and Governance) awareness leads to rising stakeholder expectations and regulatory pressure toward a sustainability transition. The process of sustainable development impacts different organizations and institutions, including banks which, due to their essential role as intermediaries in the financial system, channel funds into economic activity. Stakeholder expectations, regulatory pressure to report non-financial information and the need for a shift towards sustainable finance results in an increasing demand for ESG disclosure.

The aim of this article is to identify the growing importance of ESG data and the changing demands for such information at the company level for banks operating in Poland. We present an overview of the sustainable banking literature which argues that financial institutions progress from defensive compliance to proactive integration of ESG into risk management, pricing and product development. This evolution increases the demand for decision-useful, comparable and assured ESG data from corporate clients. Drawing upon the regulatory changes, we outline the concept of sustainable finance and discuss the banks' role in increasing the transparency of companies. We confront theory with practice by presenting the results of a survey conducted in 2024 and 2025 based on a sample of banks operating in Poland regarding their demands for company ESG data and the sources these data derive from.

**Keywords:** ESG data, banking sector, sustainable finance

**JEL:** M0, M1

## 1. Introduction

The growing importance of stakeholders combined with the urgency to address the challenges associated with the widely recognized global sustainability necessitate research on sustainability and Environmental, Social and Governance (ESG) standards. Today, sustainability has become a prevailing course of development in business practice. Sustainability aims at improving the well-being of various stakeholders addressing global concerns related to social inequality, human rights crisis, climate change and ineffective governance structure. Stakeholders pressure companies to balance their financial and non-financial goals as well as to incorporate sustainability strategies (Chelli et al., 2018; Tsang et al., 2023). These actions are

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operationalized into the ESG metrics on performance and disclosure standards and are expected to broaden the assessment of business activity and measure the progress towards a sustainable transition (Cho et al., 2012; Stacchezzini et al., 2016).

A firm's motivation for incorporating ESG practices in business strategies (Tsang et al., 2023) is driven by several reasons. Firstly, sustainability is perceived as a means to strengthen the competitive advantage of a company (Ioannou & Serafeim, 2019) and allows it to distinguish itself from its rivals in the market (Goyal et al., 2013). Superior ESG performance becomes of strategic importance for company operations; it can improve firm reputation and image (Zhang et al., 2022), gain customer loyalty and increase revenues. Higher ESG performance is expected to improve corporate financial performance and firm value (Paolone et al., 2022). Secondly, improving ESG performance is also seen as a rational company response to institutional pressures from regulators who introduce legislations on ESG disclosure and taxonomy for financing policy, investors searching for lower reputational risk (Yu et al., 2018) and stakeholders who expect practical solutions toward sustainability.

The existing literature offers studies on various aspects of sustainability transition, including the development of ESG disclosure and performance (Hassan & Romilly, 2018), its company- and country-level determinants (Gao, 2011) and the process of its institutionalization. Moreover, these studies investigate the impact that the introduction of sustainable solutions has on organizational change (Lozano et al., 2016) and financial performance (Alareeni & Hamdan, 2020; Saygili et al., 2022).

The effective implementation of sustainability at the company level requires institutional support, characterized by coercive regulatory requirements and enforcement pressure from the financial system. Economic activity requires financing, thus banks, investors and other institutions in the financial system play a crucial role in shaping the directions for business development with regard to sectors, products, services and compliance requirements. In other words, capital providers, with their capacity to channel funds across the economy, are able to translate stakeholders' expectations toward sustainability into lending and risk policies that drive sustainable development (Jeucken & Bouma, 2017). Therefore, banks may diffuse sustainability practice (Aracil et al., 2021; Yip & Bocken, 2018) and determine not only the development of particular industries but also shape the company practices to comply with ESG standards on emission, water use or human rights. As ESG indicators translate into criteria for obtaining credits, companies that fail to meet the bank's guidelines may face restricted access to financing, thereby limiting their development (Lu, 2024).

In this context, we identify the research gap regarding the insufficient understanding of the ESG data required by the financial system, particularly by

banks which allocate funds amongst different corporate clients in the process of stimulating sustainable development (Carè, 2018; Menicucci & Paolucci, 2023; Nykvist & Maltais, 2022). The existing studies indicate that the role of ESG data reported by companies and used by banks is far from being overestimated, especially given the extensive shortcomings of the reported information (Rajawat & Mahajan, 2025). While the existing literature offers extensive evidence on the evolution of ESG metrics and its impact on the performance and financing of companies, scholars indicate several limitations of the prior research focusing on ESG data (Chaidali & Jones, 2017). Moreover, the lack of empirical consensus in research on ESG is attributed to certain methodological shortcomings, including inconsistent terminology and nomenclature, the absence of standardized data, the use of different measures for corporate ESG performance and material and immaterial ESG issues tend not be treated separately (Whelan et al., 2021). As a result, scholars and practitioners face difficulties comparing ESG performance across periods, firms and sectors. Furthermore, these limitations prevent reaching a consistent consensus on the ESG disclosure practices in relation to their determinants, entailed organizational change and financial performance (Platonova et al., 2018; Xie et al., 2019).

In this article, we analyze the importance of ESG data which companies provide to the market participants and stakeholders and which are essential from the perspective of the banking sector (Ling et al., 2025), while acknowledging the shortcomings of sustainability metrics and the measurement methodology. Financial institutions screen their clients for sustainability progress, potential controversies and incompliance, which complement the metrics on ESG performance (Elamer & Boulhaga, 2024). They integrate ESG variables to the construction of rating models, sector scorecards and portfolio dashboards, which increases the demand for standardized, machine-readable and assured corporate data. Since, as discussed above, ESG issues affect market, operational and reputational risks and determine company performance, banks need comparable and forward-looking indicators to understand the potential risks and prospects of their corporate clients (Carè, 2018). Well-structured, comparable, reliable and material information enables banks to calibrate their pricing, set collateral haircuts and establish appropriate covenants and portfolio limits. ESG data is also driven by consulting agencies, which produce ratings depicting potential risks and the financial sector, which evaluates investment and credit risks based on the sustainability performance of a company (Escrig-Olmedo et al., 2010).

The aim of this article is to identify the current and emerging practices of ESG data analytics regarding the demand for this type of data and access to particular topics and metrics. In particular, we investigate how banks operating in the Polish

market formulate their ESG data requirements for their corporate clients and what procedures they employ to obtain these data.

## **2. Disclosure of company ESG data**

### **2.1. The importance of ESG data at the company level**

ESG data disclosure is currently one of the most dynamically developing themes in the area of management studies. It remains, however, a complex and evolving issue. The existing literature and business practices distinguish between disclosure (Rupley et al., 2012), reporting (Michelon et al., 2015) and accounting (Norman & MacDonald, 2004). Different topical areas such as ESG (Bernardi & Stark, 2018), sustainability (Chelli et al., 2018), social and environmental, climate-related or carbon (Pellegrino & Lodhia, 2012), non-financial, corporate social responsibility (Chauvey et al., 2015), triple bottom line (Norman & MacDonald, 2004), integrated reporting (Frias-Aceituno et al., 2014) and disclosure of corporate controversies (DasGupta, 2022) are also accounted for. Bearing in mind these differences in terminology, ESG reporting generally refers to the communication of social, environmental and governance performance (Bernardi & Stark, 2018), targeted at particular stakeholder groups and society at large, and is often referred to as financial reporting (Frias-Aceituno et al., 2014).

The growing interest in ESG information at the company level results from several factors. ESG disclosure complements traditional financial reporting, which provides a broad picture of company performance, including its impact on the society and the environment. Companies are motivated to report on their social and environmental policies and activities in response to the expectations of a variety of stakeholders: regulators, non-governmental organizations, social and environmental activist groups, customers, communities, investors, and others (Chuah et al., 2020). Thus, companies pressured to disclose information about their non-financial performance are believed to have a more balanced approach and incorporate stakeholder expectations into their strategies.

Scholars assume that this increased transparency should be perceived as the strategic direction of a firm's development, affecting the overall management of the company, its culture and leadership style. For instance, studying the concept of integrated reporting, de Villiers et al. (2017) indicate that it is an element of a different philosophy which focuses on disclosing future value creation linked to the firm's strategy, business model and the six forms of capital, i.e. financial, manufactured, intellectual, human, social and natural capital. ESG disclosure is also likely to potentially change how organizations perceive their social investment

activities towards value creation and how they link them to strategy (Bose et al., 2022). Furthermore, Gond and Moon (2011) find that ESG reporting is employed across organizations as an adaptation or learning tool, as it can be relevant not only for strategy implementation (diagnostically for compliance verification), but also for strategy making (interactively for development assessment). In conclusion, the strategic approach to ESG disclosure contributes to the integration of the stakeholder's perspective into corporate strategy, thereby facilitating sustainability transition.

Disclosure also offers a number of financial benefits such as higher future cash flows (Qiu et al., 2016), higher performance (Xie et al., 2019) and profitability (Chen et al., 2018; Li et al., 2018). Greater transparency is associated with lower costs of equity capital (Baboukardos & Rimmel, 2016) and a general premium in financial markets, e.g. higher net earnings of the company (Berthelot et al., 2012). Moreover, ESG disclosure is crucial for market analysts, as it increases the accuracy of company forecasts (Bernardi & Stark, 2018).

Finally, ESG transparency serves as a tool of communication which companies use to gain legitimacy amongst constituencies and respond to the institutional environment (Baldini et al., 2018). Odriozola and Baraibar-Diez (2017) demonstrate that standardized and externally verified CSR reporting is likely to enhance company image. The aforementioned authors argue that CSR disclosure is a tool used to create and maintain the support of stakeholders, which is viewed as key to organizational success and survival.

## **2.2. ESG data within sustainable finance**

Information on a company's sustainability performance is crucial for the stakeholders. While scholars emphasize the role of customers, suppliers, employees and communities in determining company reputation, studies also recognize the importance of ESG data to the participants of the financial system (Iatridis, 2013; Martin & Moser, 2016), such as investors and banks. Amid the changing stakeholder expectations and growing regulatory pressure, banks are driven to integrate ESG-related factors into their operations.

The discussion on sustainability disclosure and ESG data used by banks and investors rests on the premise of their central role in allocating capital, directing financial flows and aligning incentives for corporate behavior (Carè, 2018, pp. 39–64). As financial intermediaries, banks evaluate risks, price future uncertainties and exert influence over the accessibility of funding across industries and companies (Aracil et al., 2021; Yip & Bocken, 2018). Thus, banks act not only as passive recipients of ESG information but also as active transmission channels of sustainability norms,

standards and regulatory expectations in the economy (Weber, 2017). In his seminal publications, Jeucken (2001) highlights that banks are the key players in sustainable development (Kumar & Prakash, 2019), balancing internal responsibility (governance, culture, ethics) with external responsibility (impact of financing). This dual approach ensures that banks manage risks while directing capital toward sustainable goals, essential for long-term viability and positive social impact (Tumewang et al., 2025). Banks undergo the transition towards sustainability under internal (direct) impacts and external (indirect) impacts. Direct impacts involve the bank's internal operations, including office energy use and paper waste, whereas indirect impacts are related to the bank's actions concerning lending and investment portfolios.

According to the theoretical foundations of sustainable banking in the process of ESG integration, banks evolve in three main stages, moving from defensive reputation management to preventive risk reduction and ultimately to proactive strategic engagement (Bouma et al., 2017; Jeucken, 2001). In the defensive stage, banks respond to social criticism and reputational exposure, relying on sustainability statements and public ESG ratings. In their evolution, banks progress to the preventive stage, in which they account for ESG factors and incorporate them into their internal risk assessment, sector policies and screening mechanisms. In the final, proactive stage, banks integrate sustainability principles into their core business mode by designing their products accordingly, linking credit pricing to ESG performance and shaping market expectations for transparent, reliable ESG data.

Thus, ESG data provide essential inputs for risk management translating into credit risks through regulatory constraints, technological shifts, physical climate impacts, supply chain disruptions and litigation exposure. For creditors, ESG disclosure provides additional information which allow information asymmetry to be lowered and to effectively understand potential risks and benefits of investing or granting loans to particular companies. ESG disclosure offers information which may potentially damage the reputation of a company or have detrimental effects on its valuation and return on investment for shareholders (Ling et al., 2025). This trend has been strengthened by EU regulations (Ottenstein et al., 2022), specifically by the Non-Financial Reporting Directive 2014/95/EU (NFRD), which came into effect in 2017. It outlined various company ESG performance requirements and policies. The legislation that followed was the Corporate Sustainability Reporting Directive (CSRD), which mandates companies to report according to the European Sustainability Reporting Standards (ESRS). In addition, the EU enacted regulations that directly address reporting by financial institutions, including the Sustainable Finance Disclosure Regulation (SFDR) and the Taxonomy Regulation, which translate into data requests for the ESRS topic-specific metrics for double materiality

assessments, taxonomy metrics on revenue, Capex and Opex. Based on SFDR frameworks, financial institutions categorize their portfolio which they need to disclose to their stakeholders. As a result, banks require ESG information from their corporate clients on such issues as greenhouse gas emissions, transition plans, biodiversity-related impacts and workforce indicators and integrate them to bank-level metrics.

### **2.3. ESG analytics**

The existing literature predominantly provides analyses results of voluntary disclosure relating to organizational and institutional determinants, organizational change, and economic and sustainability performance. However, scholars have been emphasizing the limitations of the voluntary approach (Kim & Lyon, 2011). The lack of convergence between different reporting regimes, coupled with the flexibility of standards and the deficit of assurance (Stolowy & Paugam, 2018) undermine the comparability of companies across sectors. Moreover, it hinders the evolution of the disclosure practices, making it difficult to distinguish between progress and regress in quality and scope (Aluchna, 2024). Other shortcomings include: a relatively low number of reporting companies, managerial discretion as to which topics to present in the report (leading to what is called cherry picking), no continuity in reporting particular standards (especially if a company's performance has declined), the insufficient use of metrics and techniques related to impression management, selective disclosure and decoupling. Therefore, theorists, practitioners and regulators stress the need to introduce mandatory legal requirements combined with their effective enforcement (Braam et al., 2016). Research on the determinants of sustainability reporting provides evidence that the corporate practice is strongly influenced by coercive mechanisms (García-Sánchez et al., 2016). While following reporting standards does not automatically enhance the quality of the information communicated to stakeholders, it increases the comparability and credibility of the ESG reports.

## **3. Research design and results**

### **3.1. Study goal and questions**

The aim of our study is to identify and understand the topics of ESG performance, which banks demand from the companies they do business with. Specifically, we focus on the ESG data whose publication becomes mandatory pursuant to the regulations on sustainable reporting and sustainable finance. The additional driver that motivates banks to obtain ESG data from companies is the banks' obligation to disclose their credit portfolios in relation to environmental (mostly CO<sub>2</sub> emissions),

social and governance impact by their customers. In order to achieve the goals of the study, we formulate three research questions:

RQ1: Which of the ESG data do the banks require now and which will it require in 2026 according to the provisions of the regulation?

RQ2: What sources of ESG data are used by banks to obtain the necessary information?

RQ3: What kind of support in obtaining ESG data do banks require from their stakeholders?

In order to provide answers to the formulated questions, we conducted a survey among the banks operating in the Polish market. The survey took place in 2024 and 2025 with the aim to identify the demands for ESG by banks in 2026 and beyond in the context of the European Union regulation. In particular, an online questionnaire was sent to ESG or sustainability managers of all banks in Poland. The questionnaire was divided into two parts: the first part was devoted to data/information/parameters/ESG information of bank customers, while the second part related to the expected support by banks to gain access to company ESG data. The overview of the survey structure is presented in Table 1.

**Table 1.** Survey structure and questions

PART I Data / information / parameters / ESG information of bank customers	
Environmental	
1. Data on greenhouse gas emissions/CO <sub>2</sub> equivalent to scope 1;	Options to answer:  1. Are the customer’s ESG parameters needed by the bank in the current period?; 2. Does the bank currently have access to customer ESG parameters?; 3 What source of a given ESG parameter is used by the bank?  Optional: a) Client’s ESG/non-financial report is publicly available b) Information obtained directly from the client in the form of a survey/interview c) Market sources / ESG information bases, if so, which ones?... d) Other sources, what kind?...; 4. Will the indicated data be needed by the bank in 2026 (according to the bank’s current knowledge and predictions)?.
2. Data on greenhouse gas emissions/CO <sub>2</sub> equivalent to scope 2;	
3. Data on greenhouse gas emissions/CO <sub>2</sub> equivalent to scope 3;	
4. Greenhouse gas emissions on FTE;	
5. Greenhouse gas emissions per unit of product produced;	
6. The energy mix of the subject;	
7. Energy consumption per unit of area / unit of production;	
8. Energy Performance Certificate of the building (Energy Performance Certificate);	
9. Information about the identified physical risks;	
10. Environmental management policies/procedures;	
11. Environmental management system standards and certificates (e.g. ISO 14001);	
12. Biodiversity policy;	
13. Water consumption;	
14. Waste management;	
15. Information on circularity of the business model;	
16. Complaints and controversies in the area of environmental impact;	
17. Environmental penalties;	
18. EU Taxonomy Compliance Data;	
19. Other?;	

**Table 1.** Survey structure and questions (cont.)

PART I Data / information / parameters / ESG information of bank customers (cont.)	
Social	
20. Human resources management policy/procedure; 21. Number of employees/FTE; 22. Number of employees/FTE, broken down by form of employment; 23. Employment structure by gender; 24. Employment structure by age; 25. Employment structure by nationality; 26. Occupational health and safety policy/procedure; 27. Number of accidents; 28. Accident severity; 29. Anti-discrimination policy/procedure; 30. Number of cases of discrimination; 31. Information on the whistleblowing system; 32. Number and type of irregularities reported; 33. Number of training hours per employee/FTE; 34. Gender pay gap in base salary; 35. Total gender pay gap (base + variable + bonuses + other components); 36. The ratio of the salary of the highest paid employee to the median salary; 37. Complaints and controversies in the employee-related matters; 38. Penalties in the employee area; 39. Other?;	Options to answer:  1. Are the customer's ESG parameters needed by the bank in the current period?; 2. Does the bank currently have access to customer ESG parameters?; 3. What is the source of a given ESG parameter used by the bank? Optional: a) Client's ESG/non-financial report publicly available b) Information obtained directly from the client – in the form of a survey/interview c) Market sources / ESG information bases, if so, which ones?.. d) Other sources, what kind?.. 4. Will the indicated data be needed by the bank in 2026 (according to the bank's current knowledge and predictions)?
Governance	
40. Code of Ethics; 41. Anti-corruption policy; 42. Number and type of identified cases of corruption; 43. Description of the supply chain; 44. Supplier evaluation mechanism in the field of ESG/CSR; 45. Certificates used in the supply chain; 46. Diversity of the members of the management and supervisory staff in terms of gender; 47. Diversity of the members of the management and supervisory staff in terms of age; 48. Diversity of the members of the management and supervisory staff in terms of nationality; 49. Production quality management certificates (if relevant to the client's business); 50. Product safety certifications; 51. Certified production/services (type of certification and share of certified production); 52. Number of customer information breaches; 53. Number of cases of complaints and violations in the field of marketing communication; 54. Other?;	Options to answer:  1. Are the customer's ESG parameters needed by the bank in the current period?; 2. Does the bank currently have access to customer ESG parameters?; 3. What is the source of a given ESG parameter used by the bank? Optional: a) Client's ESG/non-financial report publicly available b) Information obtained directly from the client in the form of a survey/interview c) Market sources/ESG information bases, if so, which ones?.. d) Other sources, what kind?.. 4. Will the indicated data be needed by the bank in 2026 (according to the bank's current knowledge and predictions)?

**Table 1.** Survey structure and questions (cont.)

PART I Data / information / parameters / ESG information of bank customers (cont.)	
Managing ESG	
55. ESG/sustainability/non-financial report; 56. ESG ratings that the client submits to and their current performance;	
PART II Information on support obtained by the bank in accessing ESG data	
57. What tools/solutions and market changes in the field of customer ESG data analytics does the bank currently need? 57.1. For climate risk analysis 57.2. For the purpose of analyzing and defining the level of ESG risk, the bank needs:	Type of support/needed solutions currently identified by the bank (yes/no) Tech tools/analytical support Access to databases Customer actions Regulator support
57.3. For the purpose of identifying assets compliant with the EU Taxonomy (GAR – green asset ratio calculations), the bank needs:	
57.4. For the purpose of identifying sustainable assets, in accordance with the internal processes currently implemented by the bank, the bank needs:	Type of support/needed solutions currently identified by the bank (yes/no) Tech tools/analytical support Access to databases Customer actions Regulator support
57.5 What other challenges and needs in terms of access to data and ESG analytics, not mentioned in the study, are currently identified by the bank?.	

Source: authors' work

**3.2. Research sample**

The questionnaire was distributed to all commercial banks operating in Poland targeting the ESG/sustainability managers and directors. We obtained questionnaires from the nine largest commercial banks with the largest number of clients and the largest assets representing 50% of the population on commercial banks operating in Poland. We acknowledge the limitation of the study given its exploratory approach. Yet, our intention was to map the concerns that the banks raised in the process of accessing, interpreting and analyzing the ESG data obtained from their corporate clients. While the magnitude of the sustainability disclosure debate refers to the reporting practice at the company level, there is an insufficient understanding of the applicability of ESG data by banks, investors and other financial institutions. The characteristics of banks covered by the study is briefly presented in Table 2.

**Table 2.** Research sample

Bank	Name (in alphabetical order)	Ownership structure	Value
Bank 1	Alior Bank, as a universal bank, addresses its services to both individual and business customers. Founded in 2008 by an Italian group, Carlo Tassara. It has been a subsidiary of the PZU SA insurance company since 2015. Alior Bank is one of the fastest growing banks in Poland. It is the first start-up bank which from the very beginning of its activity has been committed to innovation and trend-setting in online banking in the Polish market.	Alior Bank SA is listed on the Warsaw Stock Exchange (WSE) since 14th December 2012. Shareholder composition at the end of 2022 (Alior Bank, n.d.b): <ul style="list-style-type: none"> <li>• PZU S.A. Group 31.91%</li> <li>• Nationale-Nederlanden OFE 9.47%</li> <li>• Allianz OFE 8.83%</li> <li>• Generali OFE 5.56%</li> <li>• Other shareholders 44.23%</li> </ul>	<i>'In our day-to-day activities, we combine principles of traditional banking with innovative solutions, through which we systematically strengthen our market position and set new directions for development of the Polish banking sector.'</i> (Alior Bank, n.d.a).
Bank 2	Bank Gospodarstwa Krajowego (BGK) is a state development bank, established in 1924, supporting social and economic development of Poland and its public sector. BGK provides funding for infrastructure investments and thus supports the growth of this sector of the economy. It thereby creates an important link in the provision of funding and support for areas such as housing infrastructure, sustainable energy and public utilities. BGK supports Polish exporters by taking on part of the risk related to trading activities of Polish companies.	Stated-owned development bank.	<i>'Our mission is to support sustainable social and economic growth of our country. In 2025, we want to be the leader in creating and implementing the programs that enhance a stable and competitive economy, supported by strong social capital. We respond to major development challenges in key areas of the economy, we cooperate with the market and stabilize it, and also adjust our activities to the emerging needs, trends and market challenges through BGK strategy pillars and program.'</i> (BGK, n.d.).
Bank 3	BNP Paribas Bank Polska (formerly Bank Gospodarki Żywnościowej SA-BGŻ Bank) is a universal commercial bank providing innovative financial solutions in a responsible manner to help clients and to support the local economy. BNP Paribas Bank Polska offers savings and investment products as well as a wide range of loans to individual and business clients (micro enterprises, SMEs and corporates). BNP Paribas Bank Polska also pays special attention to companies from the food and agricultural sectors.	Listed on the WSE, the Bank's shareholder structure as of 5th April 2023 (BNP Paribas, n.d.b): <ul style="list-style-type: none"> <li>• BNP PARIBAS in total: 87.35%</li> <li>• Other shareholders 12.65%</li> </ul>	<i>Mission</i> <i>'We implement positive banking into the lives of our Clients, responding to their financial needs and making it easier for them to achieve their goals. We operate in a simple, thoughtful and safe manner, caring for the society and the environment.'</i> (BNP Paribas, n.d.a).

**Table 2.** Research sample (cont.)

Bank	Name (in alphabetical order)	Ownership structure	Value
Bank 4	Credit Agricole is a universal bank that has been present in the Polish market since 2021. It offers banking services to retail customers and corporations, to farmers and SMEs, as well as consumer finance services.	Part of the Credit Agricole Group – the 10th largest financial group in the world.	The bank motto, is: <i>'Working every day in the interest of our customers and society'. This means that the customer is at the center of our attention: we listen carefully to our customers and deliver the solutions they need.'</i> (Credit Agricole Bank, n.d.).
Bank 5	ING – in June 2001, ING Bank became a major shareholder of Bank Śląski and on 6th September 2001, Bank Śląski, a member of the ING Group, started operating under a new name – ING Bank Śląski SA. ING Bank Śląski is a universal bank, offering a broad range of retail, corporate and private banking products and services to individual and corporate customers.	Listed on the WSE since 1994, current shareholder structure: (ING Bank Śląski, n.d.b): <ul style="list-style-type: none"> <li>• ING Bank N. V. 75.00%</li> <li>• Allianz Polska Otwarty Fundusz Emerytalny 9.30%</li> <li>• Other shareholders 15.70%</li> </ul>	<i>'Our mission: at ING Bank Śląski, we support customers to be one step ahead in life and in business, including in ESG. That is why ESG strategy is part of our business strategy. It is important to us because the future is our shared responsibility.'</i> (ING Bank Śląski, n.d.a).
Bank 6	mBank was established in 2000 as BRE Bank, the bank was rebranded to mBank in 2013. mBank is one of the largest Polish banks, operating as a universal bank and serving all client groups, leading in terms of mobility and innovations. mBank provides a comprehensive range of products and services in retail, business, corporate and private banking.	Listed on the WSE since 1992. At the end of 2022, CommerzBank AG owned 69.17%, meantime 30.83% of shares was in free float. (mBank, n.d.b).	<i>Values of mBank Group:</i> (mBank, n.d.a). <ul style="list-style-type: none"> <li>• Authenticity</li> <li>• Empathy</li> <li>• Responsibility</li> <li>• Courage</li> <li>• Cooperation</li> </ul>
Bank 7	Bank Millennium is a nationwide universal bank, offering its services to all market segments through a network of branches, individual advisors and electronic banking. Bank Millennium was established in 1989 as Bank Inicjatyw Gospodarczych. In 1997 it changed its name to BIG Bank GDANSKI and in 2003 to the present name	Bank Millennium has been listed on the WSE since 1992; it was the first Bank ever to float its shares on the WSE. Banco Comercial Portugues (Millennium bcp) – Portugal's largest commercial bank and Bank Millennium's strategic shareholder (owner of 50.10% of the Bank's shareholding).	<i>The mission of Bank Millennium is to support our customers to succeed in their financial present and future. The Bank's goal, stemming from its mission, is to deliver premium quality universal financial services to all customer groups and live up to the development challenges of Poland's financial services market, which should bring constant increase of the Bank's value to Shareholders.'</i> (Bank Millennium, n.d.).

**Table 2.** Research sample (cont.)

Bank	Name (in alphabetical order)	Ownership structure	Value
Bank 8	Bank Pekao, an international universal bank, is the largest corporate bank and the leader of the private banking market in Poland. The bank was founded in 1929 by the Ministry of Treasury as a national bank, mainly to provide financial services to Poles living abroad. In 1939, the bank had branches in virtually every capital city of the countries where Poles lived. Historically, the Italian bank UniCredit used to own 59% of the company, then it was sold. In 2017, the process of acquiring Bank Pekao S.A. shares by Powszechny Zakład Ubezpieczeń and the Polish Development Fund was completed.	Since 1998, the bank has been listed on the WSE. Shareholding structure as of the 2022 Report: <ul style="list-style-type: none"> <li>• Powszechny Zakład Ubezpieczeń S.A. 20.00%</li> <li>• Polski Fundusz Rozwoju S.A. 12.80%</li> <li>• Funds managed by Nationale-Nederlanden Powszechnie Towarzystwo Emerytalne S.A. 6.40%</li> <li>• Funds managed by Powszechnie Towarzystwo Emerytalne Allianz Polska S.A. 5.91%</li> <li>• Subsidiaries managed by BlackRock, Inc 5.04%</li> <li>• Other shareholders 49.85%</li> </ul>	Mission: <i>'Simple and safe banking world.</i>  <i>For almost a century we are setting the standards on the market. We are a reliable partner in the everyday life of millions of Poles. We help to make dreams come true and to pursue passions. We have positive impact on the economy, we build strong relationships with entrepreneurs and provide safety to our customers. We put innovative services into practice in an easy and friendly way'</i> (Bank Pekao, n.d.).
Bank 9	Santander Bank Polska (formerly Bank Zachodni WBK) was established in 2001 as a result of a merger between Bank Zachodni S.A. and Wielkopolski Bank Kredytowy S.A. (WBK). In 2011, Bank Zachodni WBK became a member of Santander Group. Santander Bank Polska SA offers financial solutions for individuals, micro enterprises and SMEs, as well as Polish and international corporations.	Shareholders structure (Santander, n.d.a): <ul style="list-style-type: none"> <li>• Banco Santander S.A. 67.41%</li> <li>• Nationale-Nederlanden OFE 5.01%</li> <li>• Other shareholders 27.58%</li> </ul>	<ul style="list-style-type: none"> <li>• <i>Purpose</i> <i>To help people and businesses prosper. To be the best open financial services platform by acting responsibly and earning the lasting loyalty of employees, customers, shareholders and communities.</i></li> <li>• <i>Values</i> <i>Simple, Personal, Fair</i> (Santander, n.d.b).</li> </ul>

Source: authors' work based on the websites of the sample banks.

Polish banks attempt to align with the UN Sustainable Development Goals (SDGs), although this sector lacks a universally accepted model, with approaches varying between internal resource management and external portfolio steering. The overview of the sample banks, however, indicates a shift from treating ESG as a side project to making it an important element of their business models. For instance, Santander Bank Polska has become the first bank in Poland to issue sustainable debt securities totaling PLN 750 million. In a similar vein, mBank has rewritten its rulebook for green transformation and allocated PLN 22 billion to sustainable investments, doubling its original strategic targets. As the largest market player, PKO BP

is working through its 2025–2027 strategy to bring over half of its large loan portfolio into the transformation plan, cutting its own Scope 1 and 2 emissions and increasing the use of green bonds. Finally, BNP Paribas Bank Polska, moved beyond the goals with its ‘Accelerate 2030’ strategy and targeted the decarbonization of the agrifood sector through a dedicated Sustainable Development and Agribusiness Area, while Bank Pekao S.A. ensured a stable, reliable source of funding for complex ESG projects.

### 3.3. Results

Addressing the first research question (RQ1), we asked the respondents about the types of the ESG data which the bank requires now and the ones it will need to obtain, as demanded by EU regulations. As shown in Table 1, we divided the topics of ESG data according to environmental, social and governance dimensions. When dealing with the environmental dimensions, respondents indicated that the company ESG parameters needed by the bank currently include data on greenhouse gas emissions/CO<sub>2</sub> equivalent in scope 1 and scope 3, followed by information about the identified physical risks and environmental management policies/procedures (each selected by 4 banks). Next, we learned that the banks predict a growing demand for additional ESG data according to the currently known legislation procedures. The highest number of answers was depicted for greenhouse gas emissions on FTE and greenhouse gas emissions per unit of product produced (all sample banks), biodiversity policy (8 banks), the energy mix of the subject and energy consumption per unit of area/production, water consumption, waste management and circular economy (7 banks).

Next, RQ1 was used to analyze the responses on social information within ESG data. The number of items that banks found important now is similar to the case of the environmental information. Four banks pointed at the information about fines in employee-related matters, while three banks emphasized the importance of the information on the number of employees/FTE, occupational health and safety policy/procedure, the number and severity of accidents, as well as the number of cases of discrimination. The greatest interest in the social information for 2026 notified by the respondents refers to the information on the employment structure by nationality (9 banks) and by age, information on the whistleblowing system and the number and type of irregularities reported, the number of training hours per employee/FTE and total gender pay gap (8 banks), followed by information on the employment structure by gender, occupational health and safety policy/procedure, the number of accidents, the number of cases of discrimination, gender pay gap in base salary and complaints and controversies in employee-related matters (7 banks).

With respect to governance information data, which banks perceived as needed currently covers code of ethics (5 banks), followed by the information on anti-corruption policy (4 banks) and the number and type of identified cases of corruption, certified production/services, diversity of members of the management and supervisory staff in terms of gender (3 banks). Banks submitted the demand for the following ESG metrics – diversity of members of the management and supervisory staff in terms of age and nationality (8 banks), followed by the number and type of identified cases of corruption, the description of the supply chain, the supplier evaluation mechanism in the field of ESG/CSR, certificates used in the supply chain, production quality management certificates, product safety certifications, certified production/services and number of customer information breaches (7 banks).

Overall, while banks demand ESG data now, the survey results indicate that they anticipate a significant increase in ESG data availability. The increase refers to all dimensions with social metrics identified as the most dynamically growing aspects of ESG data. Our findings show that, as indicated by the sustainable banking theory, the sample banks anticipate the need for more detailed ESG information from corporate clients (Weber, 2017), proceeding from a defensive approach (focused on addressing reputational risks) to a preventive and proactive approach (Bouma et al., 2017; Jeucken, 2001). It should be noted that the increased demand for data corresponds with the banks' shift toward integrating environmental risks into credit risk models and portfolio management according to material principles on environmental performance. Additionally, the evidence points to increased social data needs, which aligns with the global trend in banking toward assessing human capital quality as a component of long-term creditworthiness. The existing literature demonstrates that weaknesses in workforce management, discrimination or health and safety translate into operational and legal risks that may affect a borrower's financial stability (Goyal & Joshi, 2011). Banks' increasing demand for social metrics on diversity, pay ratios and whistleblowing systems provide a means to strengthening the monitoring of social controversies that may undermine their credibility or reputation (Wang, 2023). A similar logic drives the demand for governance-related metrics, particularly covering anti-corruption systems, board diversity and supply-chain oversight.

The second research question (RQ2) referred to the sources of ESG data used by banks to obtain necessary information. According to the survey results, respondents pointed at non-financial reports published by companies as the main sources of these four areas of ESG company data. In addition, one bank uses the klimada.pl publicly available website to learn about the physical risks, two banks conduct a separate questionnaire among their clients to obtain any necessary data. Moreover,

two banks claimed that they obtained data directly from companies and one bank emphasized the role of personal relations to get access to ESG data from the client company. These findings suggest the ESG data infrastructure is in its transitional stage, during which banks still rely heavily on self-reported information, despite the known problems of inconsistency, selective disclosure and greenwashing (Haji et al., 2023). The literature on the non-financial disclosure by banks themselves points to similar risks, stressing that a high level of ESG disclosure does not necessarily imply alignment with sustainability performance or transparency. The reliance on client questionnaires and relational channels confirms that bank-level ESG integration cannot progress to the next, proactive stage until standardized, machine-readable and assured data are obtained. Such a practice has been widely noted also in studies on institutional investors who directly approach their portfolio companies to collect reliable and customized ESG data (Aluchna, 2024; Semenova, 2023).

The final research question, RQ3 focuses on the support that the sampled banks require in accessing ESG data. Respondents pointed to all the formulated support for all three dimensions, emphasizing access to databases, customer actions and regulator support (8 banks), followed by technical tools and analytical support (7 banks). We interpret these observations as a recognition of ESG data management as a critical capability gap requiring structural investment. As the sustainable finance literature suggests, banks need enhanced data platforms, advanced analytics and supervisory guidance to translate ESG information into coherent risk assessments (Steiner & Makarenko, 2025, pp. 65–102). The demand for regulatory support, reflected by the sector’s expectations, involve developing efficient and coherent reporting standards, assurance requirements and supervisory frameworks that would reduce data asymmetries and increase reliability across corporate borrowers. The results of the survey are summarized in Table 3.

**Table 3.** Summary of survey findings

Research aspect	Main findings	Implication for banks
Type of ESG data required	All three types, i.e. environmental, social, governance. Concerns about controversies or incompliance.	Increasing demand for data on environmental and social impacts, as well as value chains. Inclusion of ESG into banks’ policies.
Source of ESG data	Company, non-financial reports, bank’s direct access to company via questionnaires.	Growing importance of metrics to enhance comparability. Bank’s demand for stronger infrastructure.
Support in accessing the ESG data	Databases, customer actions and regulatory support.	Growing importance for technical and analytical tools supporting banks.

Source: authors’ work.

The research results show that banks are well aware of the growing need for ESG data, driven by the increasing impact of ESG information (Xu et al., 2025) on financial performance and reputation (Samaniego-Medina Reyes & Giráldez-Puig, 2022). Furthermore, ESG transparency is also determined by EU regulations, which will most likely lead to the further expansion of the scope of the reported information. The enhancement of disclosure is noted within all of the ESG dimensions: environmental data providing information on emissions, waste management, water consumption across the value chain, including the performance of suppliers and subcontractors. The demand for social information with regard to the characteristics of employees (gender, age), anti-discrimination measures, gender pay gap and occupational health and safety will also increase. Again, the scope of the data will also include information from suppliers and subcontractors. Finally, additional attention will be given to governance data referring to anti-corruption measures and policies, cases of corruption, diversity of boards, as well as certification along supply chains. The regulatory change results in a significant demand for data on ESG performance and policies leading to the development of a reporting framework, reporting standards and for metrics and indices. To ensure regulatory compliance, both companies and banks have to engage IT specialists, experts in quantitative methods and auditors to avoid any structural constraints (Menicucci & Paolucci, 2023).

In summary, the increasing demand for ESG data, efforts to enhance data accessibility and infrastructure development appear to follow the trajectory conceptualized by Jeucken (2001), moving from defensive behavior toward a proactive strategy of ESG data integration into banks' policies. The increasing demand for detailed, value-chain-wide ESG indicators reflects the attempts of the banking sector to integrate sustainability into credit assessments, pricing policies and portfolio management (Bouma et al., 2017; Goyal & Joshi, 2011). Supporting banks with metrics, methodology, assurance and infrastructure determines their position since the associated costs and structural shortcomings may undermine their potential to contribute to sustainability (Nykvist & Maltais, 2022).

## 4. Conclusions

Addressing stakeholder expectations for greater transparency and substantive actions towards decreasing the negative impact of business on society and environment creates a strong demand for ESG data. ESG data provide a bigger picture of company performance and become an essential tool used to manage a company's transition towards sustainable economy.

These trends have been strengthened in recent years in the EU with a package of regulations that pressure companies to redevelop their business models to comply with the principles of sustainability. In addition, to accelerate the transition process, more emphasis was put on the financial sector in order to redirect the capital towards sustainable projects. As a result, banks as well as other financial institutions are required to report the composition of their credit and investment portfolios. The goal of the regulation is to limit the financing for companies with a negative impact and channel the capital toward green solutions.

The goal of our study was to confront the regulatory framework for ESG data with the practice and plans of the banks operating in the Polish market. The survey carried out on a sample of nine commercial banks representing about 50% of the market share revealed that the banks are aware of the emerging expectations. The results document the evolving requirements for ESG data by banks. While at present the findings indicate the need for selected types of ESG information, they also signal a significant increase of demand for ESG data. The answers collected from sustainability experts in the sample banks indicate that the form, accuracy and credibility of the reported ESG information is expected to increase in the following years.

Our study provides significant implications for both practitioners and policymakers. Firstly, the results suggest that banks move along the sustainable-banking maturity path outlined in Jeucken's (2001) framework, evolving from defensive, reputation-oriented behavior toward proactive ESG integration. Given the central role of banks in the financial system, our results imply that banks can function as transmitters of sustainability norms by requiring standardized and assured ESG data from their corporate clients.

Secondly, given the magnitude of the change, we suggest policymakers consider the institutional and expertise support for companies and banks which will operate under sustainability regulations. Adjusting the reporting and IT systems will require a significant effort from both companies and banks. The assistance provided by policymakers would support the enforcement of sustainability regulations and assure a more effective implementation of the new practices. There is a growing need and market hope for building a central ESG database, whose goal would be to gather the data from entities (reporting companies) in one place. Access would be provided to investors, regulators and financial institutions, including banks, to allow them the use of reliable data, necessary for their ESG analysis. The provision of effective and systematic solutions in ESG data management will require a strong collaboration between the players in the financial market, coupled with support and supervision from regulatory bodies.

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# Report from the 34th Scientific Conference of the Classification and Data Analysis Section of the Polish Statistical Association

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## 1. Introduction

The 34th Scientific Conference of the Classification and Data Analysis Section of the Polish Statistical Association took place on 23rd–24th September 2025, in Wrocław, Poland. It was organized by the Classification and Data Analysis Section (Sekcja Klasyfikacji i Analizy Danych – SKAD) of the Polish Statistical Association (Polskie Towarzystwo Statystyczne – PTS) and the Wrocław University of Economics and Business (WUEB). Basic information about the conference is available at <https://www.skad.edu.pl/skad2025/>.

Krzysztof Jajuga, PhD, DSc, ProfTit (WUEB), chaired the organising committee, which included Andrzej Dudek, PhD, DSc, Assoc. Prof. at WUEB, Katarzyna Kuziak, PhD, DSc, Assoc. Prof. at WUEB, Aleksander Mercik, PhD, DSc, Assoc. Prof. at WUEB, the Scientific Secretary of the Conference, Marcin Pełka PhD, Assoc. Prof. at WUEB and Marek Walesiak, PhD, DSc, ProfTit.

The aim of the SKAD conference was to provide a platform for the exchange of ideas related to the theoretical and applied aspects of classification and data analysis, to present the latest research in this area and to indicate its possible development directions. The following topics were addressed during the conference:

- theoretical aspects of classification and data analysis: taxonomy, graphical methods, discriminant analysis, linear ordering methods, multivariate statistical analysis, methods of analyzing continuous and discrete variables, symbolic data analysis, machine learning methods, and artificial intelligence;
- application: financial data analysis, marketing data analysis, spatial data analysis, computer application of statistical methods, and other areas of the application of data analysis such as medicine, psychology and archaeology.

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The conference featured 51 participants, including faculty members and doctoral students from the following universities and institutions: Wrocław University of Economics and Business, Leiden University, Statistics Poland, University of Rzeszów, University of Łódź, Institute of Environmental Protection – National Research Institute, University of Szczecin, Krakow University of Economics, Jan Kochanowski University of Kielce, Nicolaus Copernicus University in Toruń, University of Warsaw, Mazovian Academy in Płock, Poznań University of Economics and Business, Statistical Office in Poznań, University of Economics in Katowice, Warsaw University of Life Sciences, University of Gdańsk, Federal University of Bahia, Adam Mickiewicz University, Poznań, Maria Curie-Skłodowska University in Lublin, StatSoft Poland, and EMPIRICA Ltd.

A total of 32 presentations introducing research results related to the theory and application of classification and data analysis were made during five plenary sessions, six parallel sessions, and a poster session. The sessions were chaired by Józef Pociecha, Eugeniusz Gatnar, Paweł Lula, Krzysztof Najman, Marek Walesiak, Andrzej Dudek, Marcin Salamaga, Grażyna Dehnel, Kamila Migdał-Najman, Katarzyna Kuziak and Joanna Landmesser-Rusek.

Below is a list of all papers presented during the conference:

- Mark de Rooij, *Reduced Rank Regression for Mixed Predictor and Response Variables*;
- Marek Cierpień-Wolan, *Statistics in a Hyper-Turbulent Era*;
- Józef Pociecha, Marek Walesiak, Krzysztof Jajuga, *The Section of Classification and Data Analysis of the Polish Statistical Association – a bit of history*;
- Andrzej Dudek, *Data Preprocessing Step in Forecasting with Deep Learning Models*;
- Paweł Rokita, Radosław Pietrzyk, Piotr Grzybowski, *Toxic Order Flow, VPIN Spikes, and Price Changes: Implications for Market Makers in Unregulated Crypto-Token Market*;
- Beata Bieszk-Stolorz, *Survival Time Entropy in Assessing the Chances of Taking Up Employment*;
- Krzysztof Dmytrów, *Multidimensional Evaluation of Linear Ordering Methods in Location Selection During Order Picking*;
- Joanna Michalak, Małgorzata Szczepaniak, *Profiling Attitudes Toward Income Inequality in Poland Using Cluster Analysis*;
- Volodymyr Melnykov, *Conditional Mixture Modelling with Applications*;
- Paweł Lula, *Methods for Classifying Text Documents*;
- Krzysztof Najman, Kamila Migdał-Najman, *Explainable Artificial Intelligence – A Step Toward Increasing Trust in AI Models*;

- Joanna Trzęsiok, *On Discrimination Without Bias*;
- Katarzyna Raca, Alisson Soares, *Discussions Around the “Great Reset” Theory on Reddit: Content and Dynamics Analysis*;
- Janusz Wątroba, *Accounting for Additional Sources of Variability When Assessing Statistical Significance of Effects*;
- Marta Dziechciarz, Marcin Pełka, *Linear Ordering Based on Symbolic Histogram Data*;
- Monika Świącchochowska, Łukasz Smaga, *Random Projections Method in Multifactor Analysis of Variance for Functional Data*;
- Joanna Landmesser-Rusek, *GAT Neural Networks in Exchange-Rate Modelling*;
- Marcin Salamaga, *Examining the Impact of Firms’ Internationalization on Their Digital Innovativeness Using Structural Equation Modelling*;
- Dorota Rozmus, *Impact of Current and Expected Inflation on Assets of Public-Sector Manufacturing Enterprises*;
- Tomasz Klimanek, Sylwia Filas-Przybył, *Assessing the Impact of Changes in Temporal Accessibility on Permanent-Residence Migration*;
- Kamil Zientarski, *On the Correctness of Selecting and Weighting Diagnostic Variables in Taxonomic Procedures*;
- Marcin Pełka, Aneta Rybicka, *Studying Beer Consumer Preferences Using Latent Profile Analysis*;
- Aleksander Mercik, Krzysztof Piontek, *Volatility Spillovers Between Stock Exchanges in Digital Asset Markets*;
- Marek Walesiak, Grażyna Dehnel, *Achieving SDG 4 in EU countries in relation to the target year 2030: A multivariate indicator analysis using a hybrid approach*;
- Katarzyna Kopczevska, *Spatial Association Rules for Uncovering the Urbanization-Greening Relationship: Land-Use Changes Under Population Change in Europe (2006–2018)*;
- Jacek Batóg, Barbara Batóg, *Multidimensional Analysis of Public Debt of the World’s Largest Economies*.

During the poster session, the following papers were presented:

- Andrzej Geise, *Digitalization and Innovation Impact on Export of High-Tech Products in European Countries – A Panel Data Approach*;
- Dominik Krężolek, *Nonparametric Risk Classification Methods for Selected Companies Listed on the Warsaw Stock Exchange*;
- Norbert Jaworski, *A Novel Density-Based Metric for Measuring Spatial Competition in Urban Agglomerations*;
- Michał Boda, Marta Karaś, Michał Stachura, *Beyond Traditional Risk Models A Robust Interaction-Based Framework for Systemic Risk Assessment*;

- Elżbieta Antczak, Agnieszka Sobol, *Energy Poverty in Poland – Assessment of the Situation and Spatial Trends Using a Composite Development Measure*;
- Paweł Kaczmarczyk, *VAR Models for Approximating and Forecasting the Telecommunication Market: Empirical Results on Effectiveness*.

On the first day of the conference, the members of SKAD held their annual meeting. Prof. Andrzej Dudek, the president of SKAD, chaired the meeting, which included the following agenda items:

1. Report on the activities of SKAD PTS;
2. Information on the planned national and international conferences;
3. Organization of the SKAD PTS conference in 2026 and 2027;
4. Election of the SKAD PTS Representative to the IFCS Council for the 2026–2029 term;
5. Miscellaneous matters.

Opening the session, the Chair welcomed the participants and confirmed the agenda, emphasizing the importance of continued collaboration within the scientific community and the active role of SKAD members in national and international initiatives.

The first item on the agenda was a comprehensive report on the activities of SKAD. The report summarized the developments in June 2024–September 2025. It included membership statistics, administrative matters related to GDPR declarations, maintenance of communication channels, and the availability of information resources for the members. The Chair emphasized the ongoing engagement and thanked the members for their support and involvement in the SKAD initiatives.

According to the report, SKAD currently has 231 members. Any bylaws and membership applications are available on the SKAD website. Then, a moment of silence was observed in memory of SKAD members, Alina Karska, PhD, and Cyprian Kozyra, PhD, who have recently passed away.

The report concerning the SKAD conference (which was held in Kraków on 5th–6th June 2024) could be found in issue 2/2025 of the *Przegląd Statystyczny. Statistical Review* journal (Dudek, A., Lula, P., & Pawełek, B. (2025). Report from the 33rd Scientific Conference of the Classification and Data Analysis Section of the Polish Statistical Association. *Przegląd Statystyczny. Statistical Review*, 71(2), 39–42. <https://doi.org/10.59139/ps.2024.02.3>).

The growing SKAD members' international presence was also emphasized, evidenced by their active participation in major global conferences, strengthening the visibility of the Polish research in the area of classification and data analysis, and the related fields.

The second item on the agenda concerned the planned national and international conferences. Information on important upcoming scientific meetings in Poland was presented, which included the Multivariate Statistical Analysis 2025 (4th–6th November 2025) and the Aleksander Zeliaś International Conference (11th–14th May 2026), as well as other international events: the IFCS 2026 (15th–19th July 2026), ECDA 2026 (9th–11th September 2026), the German-Polish Seminar on Data Analysis (9th–11th September 2026), and CLADAG 2027. The SKAD members were encouraged to actively participate in these events.

The third item on the agenda related to the organization of future SKAD conferences. The members were informed that the negotiations concerning the SKAD 2026 conference were underway, with mid-September 2026 as the most likely date for the event to take place. Preliminary considerations for the organization of the SKAD 2027 meeting were also briefly mentioned, with details to be determined in due course.

The election of the SKAD representative to the IFCS Council for the 2026–2029 term was the fourth item on the agenda. A scrutinizing committee composed of Prof. Eugeniusz Gatnar and Prof. Marcin Pełka was appointed. Voting was carried out among the eligible participants, ensuring a transparent and orderly procedure, consistent with the SKAD rules.

The results of the election were subsequently announced. A total of 18 votes were cast, all valid. The candidate, Prof. Andrzej Dudek, received 17 votes in favour, 1 abstention, and no votes against, thus becoming elected as the SKAD representative to the IFCS Council for the 2026–2029 term. The Chair thanked the members for their trust and expressed readiness to continue supporting international collaboration and the strategic presence of SKAD within the IFCS structures.

In the final part of the meeting, participants were invited to submit additional remarks and proposals. Appreciation was expressed for the organizational efforts related to the conference and the functioning of the section. The Chair concluded the meeting by thanking all the attendees for their active participation and constructive contributions, reaffirming the shared commitment to advancing research in classification and data analysis. Prof. Andrzej Dudek and Prof. Jacek Białek (University of Lodz) invited the members to the next SKAD conference, which will be held in Łódź or Bełchatów in September 2026.